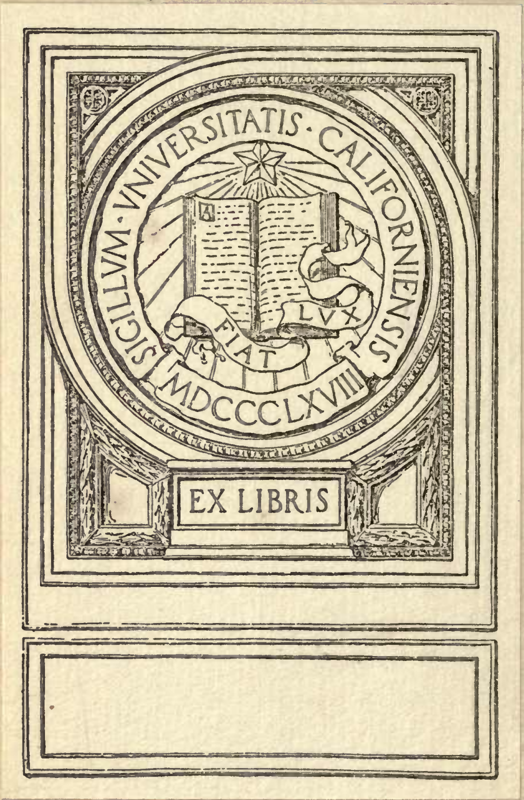
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INDUSTRIAL PLANTS

THEIR ARRANGEMENT AND CONSTRUCTION

BY

CHARLES DAY

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INTRODUCTION

The inclusion of a volume upon works construction in a library of "Works Management" is a purposeful recognition of the fact that efficiency and economy in manufacturing must consider much more than the mere operation of the plant in which the processes of production are carried on. The factors considered by Mr. Day—the arrangement and construction of industrial works—are indeed primary. They concern the organic constitution of the factory, and hence are of more potential importance even than systems of management, which concern functional conditions. Functional disorders, even if severe, may be reduced by treatment; but an organic inefficiency embodied in the design and structure of the plant itself is incurable, and is imposed in dependent sequence upon all later operations.

Mr. Day's development of the subject is thoroughly adequate to its importance. His extension of the scientific method into this relatively new field is unique. He defines for the first time, in permanent form, the principles and the practical precepts of scientific plant construction. His work, much of which appeared first in the pages of THE ENGINEERING MAGAZINE, has been developed by a true evolution, following scientific lines of progress. It is guided by intimate knowledge of the subject and directed by high ideals. It combines the interest of scientific pioneering with the certainty and authority of conclusion that characterize the master of a specialty.

THE EDITOR.

PREFACE

When conquest was for spoil and slaves, the conquerors came to regard manual effort a disgrace. Until within a century the army, church, medicine and law were the respected occupations; manufactures and trades constituted a despised class.

With steam to supersede the slave and serf came the new era of industrialism. The iron-masters, shipbuilders, spinners, weavers, and engineers, through their surprising accomplishment, took rank with the professions; they were seen to be men of the greatest ability; they attained to wealth and important positions in the government of nations.

Now their successors are bettering their methods, mechanical, manual and systematic; they have attained vastly greater efficiency, until the judgment of the scientific worker is seen to be indispensable.

We are ever struggling against tradition; but so great is the triumph that "Business" now ranks with the "Professions," being no longer imitative, or "craft," but the ability to utilize all inventions and knowledge extant, with constant individual additions and eager appropriation of all advances.

During this development each stage presented for solution certain particular problems. These were broad in the beginning, but have constantly become more specific, there being reserved for our day the detailed refinements compelled by competitive conditions arising from the collective activities of nations now engaged principally in industrial pursuits.

A striking example of the methods brought about by these conditions is the latest manner of arranging and planning industrial plants, based upon a logical scientific method of analysis which recognizes not only all physical means available, but those more subtle factors having to do with the human element—the men and women upon whom all industrial undertakings are dependent. It is with these problems that this book deals.

Chapters I to VIII, inclusive, are founded upon a series of lectures delivered before the Graduate School of Business Administration, Harvard University, and the engineering students at Columbia University. They have to do largely with the enunciation of broad industrial principles and a definition of the manner in which the arranging and planning of industrial plants should be conducted to arrive at the most satisfactory incorporation of these principles. One of these chapters is devoted to a fairly complete exposition of the use of the routing diagram as a basis for the laying out of industrial properties.

Having dealt with broad principles, the subject is considered in a more specific manner, and for this purpose the group of plants was selected whose predominating function is the working of metals.

Chapter IX treats briefly of certain of the more important problems that enter directly into the metal-working trades, and particularly machine-shop work. The object in discussing machine-tool operation and the administration of machine-shop work is to exemplify that kind of detail knowledge which should be possessed by engineers who arrange, plan, and construct industrial properties. The charts accompanying the discussion upon motor drives were published previously in a paper presented before the International Electrical Congress at St. Louis.

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Chapter X includes descriptions of the principal points of interest presented by a number of plants selected as illustrating the trend of modern practice. They exemplify results secured when the problems of planning and building are approached in a logical and thorough manner, and it is through the courtesy of the owners that this material was made available.

Chapters XI and XII bear upon the relationship of client and engineer. Many industrial managers are in full accord with the principles that are enunciated in Chapters I to X, yet are at loss to know how to secure, for their own benefit, the economies resulting through the application of these very principles.

I desire to express my indebtedness to my associates who aided in the preparation of this book, and especially to my father, Richard Day, whose assistance and constant interest have contributed materially to such merit as it may possess.

Charles Day.

December, 1910.

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INDUSTRIAL PLANTS

THEIR ARRANGEMENT AND CONSTRUCTION

Chapter I

GENERAL CLASSIFICATION OF THE WORK

INDUSTRIAL PLANTS have to do broadly with the manufacture of articles for commerce, and the problems that must be taken into account when building new plants relate to the use of machinery, the provision of shelter, the management of labor, and all other economic conditions that affect the manufacturing and marketing of the output.

It is the purpose of this and certain of the following chapters to deal with the more important factors that compose these main headings; and as only a comparatively small group of men would be interested in the detail considerations presented by a given business, an effort will be made to convey the scope of the problem as relating to industries generally, and to point out the method of attack that is necessary in any case for its proper solution. Therefore, the discussion will have to do with matters that are common, to some extent, to the building of all industrial plants, whether it be one for the manufacture of machine tools or automobiles, for the preservation of food products or for making carpet or cement or pottery, as the case may be.

Entirely new enterprises usually have a small beginning, manufacturing space being rented in a building that substantially meets the requirements, or a small plant being built that would hardly come within the class of enterprises we have under consideration. Large industries are almost always the result of a gradual growth; so that, in the majority of cases, new machinery and buildings, if at all extensive, are either additions to existing plants or are provided for the continuance of a business formerly conducted elsewhere.

Until recently industrial managers were too prone to consider that the work incident to the building of plants and factories had no intimate bearing upon their future operation. They assumed that the degree of success attainable through conducting an industrial business depended upon the efficiency with which it was managed, and failed to appreciate the limitations that can be permanently imposed during the building period. This statement is borne out by the large number of concerns that have had to labor under excessive investment charges or adverse manufacturing conditions, brought about possibly through the initial selection of unsuitable types of buildings, or because it was necessary to demolish good structures in order to make extensions, or on account of inadequate real estate for needed development, owing to the property having been improperly apportioned originally, or for other causes that will suggest themselves. The occurrence of one or more of these conditions is so usual that we must conclude that many industrial plants have been built without sufficient thought being given to existing and future needs.

Moreover, the subject is constantly assuming greater importance, owing to the phenomenal growth of the industrials in this country and abroad. Increasing confidence in their permanency is evidenced by the more general desire of administrators to provide adequately for the future, so there is now needed, in the building of industrial plants, a degree of foresight that former conditions did not often warrant. The building problem also becomes more complex as companies assume larger proportions (either as a result of development or consolidation), owing to the additional factors introduced when providing for a large amount of diversified machinery, and for the handling and control of large numbers of employees. Fortunately an understanding as to the exacting requirements of modern equipment and processes and of new systems of industrial administration and the desire to provide for the future has resulted in directing attention to the initial work incident to the building of new plants, and it is now more generally appreciated that the efficiency of any industrial establishment, in the final analysis, is governed to no small extent by the effectiveness of the work done prior to the actual commencement of building operations.

Now, as to the performance of this preliminary work, it was first assumed that those who were to operate a plant should advise the architect or engineer concerning the size, character, and internal arrangements of all buildings, and such factors as the selection and arrangement of machinery, facilities for receiving, handling, and shipping materials, etc. The supposition was that the experience required in order to pass correct judgment upon these matters was wholly outside the knowledge of those who were not directly engaged in the business in question. A marked change in policy, however, has been brought about largely by a class of administrators (the product of our large and scientifically managed industrials), who realize that they cannot hope to find, within their own specialized organizations, men possessing the broad experience and particular ability needed for the successful performance of all the diversified work required when building a new plant or making large extensions.

What has just been said will be more clear after consideration has been given to the classification of the subject appearing below. It will be evident that during the limited period needed for the designing of a new plant, almost every branch of engineering may be called into play, whereas the proper conduct of the routine work for which the plant is built may require little or no acquaintance with these. I am especially anxious that I should not be misunderstood in this regard. Those for whom the new plant is being built must in any event be counted upon to dictate primary requirements, but in the majority of cases their experience should be supplemented by the broader knowledge of others.

For the use of a better term, "Industrial Engineering" has been quite generally adopted as the name for the professional service rendered by independent engineers engaged upon such work as we have under consideration. Industrial engineers are not usually consulted until the decision to build has been reached. Such a decision is almost always followed by a desire upon the part of the principals to have the work completed at the earliest moment. This is but natural, as the need for greater facilities and accommodations for them is usually pressing. Therefore, the engineer engaged (as the owner puts it), "to prepare the building drawings," must accept as a basis much that the owner pronounces as satisfactory practice—and this is as it should be, for it is principally in regard to the broader considerations bearing on shop and factory layout that he can be of the most service. However, the combined efficiency of a new plant is in any event dependent to a marked extent upon the experience and ability of those for whom the work is being done.

The planning and constructing of an industrial plant is essentially a one-man job, so far as control is concerned, but necessarily, owing to the diversified problems that are presented, the industrial engineer must have the support of not only his principals but of the engineering and commercial organization with which he is identified.

He co-ordinates the mass of technical matter turned in to him by the various engineers engaged upon his work, and on account of his intimate acquaintance with his client's needs, aims, and resources, he is able to consider the conclusions presented from a broad standpoint that is wholly unknown to the individual workers. A man acting in this capacity must know how to co-operate successfully with other men; to establish confidence in his methods through complete frankness as to his own or his organization's limitations; and to remember constantly that it is the final result that measures the usefulness of his efforts, and that it is absolutely immaterial from what source a given suggestion may come. It is this mental attitude that marks the successful industrial engineer, and the combination of a wholly impersonal attitude, coupled with the ability to take an aggressive position when conditions warrant it, is, as a rule, acquired only after considerable service.

As the engagement of industrial engineers is constantly becoming more customary, it will be assumed that this course is followed. By doing this, the part that the owner or operators must in any case contribute to the work will be emphasized, and it will be equally clear that the creative work of the industrial engineer has to do with such matters as are not usually included in the routine experience and work of owner or operator.

The classification of our subject that has already been referred to appears below. The main and sub-headings are only briefly described, but in the discussion that follows each of these captions will be taken up in considerable detail.

CLASSIFICATIONS OF WORK INCIDENT TO THE PLANNING AND BUILDING OF INDUSTRIAL PLANTS

P.—Preliminary Service—Chapters II and III.

F.—Financing the work—Chapter IV.

D.—Detail plans and specifications—Chapter V.

C.—Construction work and installation of equipment—Chapter VI.

M.—Period of occupation and commencement of operation—Chapter VII.

The principal subdivisions of the above headings are:

(P) PRELIMINARY SERVICE

P-a. Determination of specific manufacturing requirements and compilation of data relating to present and future needs.

P-b. Determination of fundamental principles that will be followed in new plant regarding the administration of all manufacturing details.

P-c. Consideration of features exemplified by plants recently built for essentially the same class of work.

P-d. Determination of kind and amount of machinery that should be provided for immediately.

P-e. Determination of geographical location of site and whether plant should be built in business centre or suburban section.

P-f. Determination of approximate arrangement of equipment and processes based upon elemental routing and administration requirements.

P-g. Determination of floor areas required for manufacturing departments, storage departments, assembling departments, offices, etc. Also for likely future requirements.

P-h. Determination of departments which *must* be accommodated on the ground level and which *may* go on upper floors.

P-i. Determination of railroad and trucking facilities that should be available for receipt and shipment of materials.

P-j. Determination of total property area needed at once, and amount that should be reserved for the future.

P-k. Selection of property that most nearly meets the requirements dictated by study of foregoing factors. If possible it is preferable to defer purchase until completion of preliminary work.

P-l. Preparation of alternate layouts of departments, segregating them into one or more buildings of assumed types, taking into account all the foregoing factors including the selected property.

P-m. Reconsideration of all work done so far and preparation of a revised layout incorporating as far as possible the best features of the various preliminary studies. Making outline drawings of buildings.

P-n. Preparation of a classified estimate of cost based upon unit prices.

P-o. Determination whether estimated expenditure would result in a "fixed charge" consistent with the probable profits of the business, i. e., can the business carry the necessary investment.

P-p. Determination whether owner is prepared to make the total justifiable expenditure.

P-q. Revision of layouts, if required by financial limitations (P-o. or P-p. or both), and placing data and plans in suitable form to be used as a basis for the preparation of architectural and engineering drawings and specifications.

(F) FINANCING

We will assume that the owner personally provides the necessary funds and is not assisted in any way during his negotiation therefore by the industrial engineer. This is the usual condition in connection with the building of industrial plants. A detailed discussion of the elements of financing is therefore not necessary in this book.

(D) DETAIL PLANS AND SPECIFICATIONS

(To meet requirements defined by the preliminary work.)

D-a. Preparation of plans and specifications for special machinery as defined by preliminary work.

D-b. Preparation of plans and specifications for all other physical features defined by the preliminary work.

D-d. Preparation of plans and specifications for power generating, transmission, and driving equipment to meet the established requirements.

D-d. Preparation of plans and specifications for equipment needed to provide artificial lighting in accordance with fixed requirements.

D-e. Preparation of plans and specifications for ventilating and heating equipment needed to meet fixed requirements.

D-f. Preparation of plans and specifications for sanitary arrangements needed to meet fixed requirements.

D-g. Preparation of plans and specifications for fire-prevention apparatus based upon the conditions established by the preliminary work.

D-h. Preparation of plans and specifications for the complete building or buildings, to harmonize with the plans and specifications covered by headings D-a to D-g inclusive, and to meet requirements defined by preliminary work.

D-i. Preparation of plans and specifications for yard provisions that must be made to meet fixed requirements.

D-j. Preparation of contracts to accompany plans and specifications when soliciting bids, so drawn as to provide proper protection for both the owner and contractor.

(C) CONSTRUCTION WORK AND INSTALLATION OF EQUIPMENT

C-a. Selection of responsible concerns to bid upon plans and specifications and securing bids from such parties.

C-b. Tabulation of bids, conference with Owner, followed by placing of contracts.

C-c. Superintendence of building construction and yard work.

C-d. Superintendence of installation of "service equipment" and all standard and special machinery or appliances needed for industrial purposes.

C-e. Checking work as to quality and amount and approve invoices.

C-f. Certifying as to completion of contracts.

(M) PERIOD OF OCCUPATION AND COMMENCEMENT OF OPERATION

M-a. Moving equipment and accessories from old plant into the new, transferring force, and starting up work.

M-b. Correcting minor discrepancies that invariably evidence themselves after the plant as a whole is put into operation.

M-c. Training the force of administrators and operators along the lines necessary to bring about the most efficient utilization of the buildings and other facilities provided.

Chapter II

DETERMINATION OF SPECIFIC REQUIREMENTS

THE systematic analysis of the Preliminary Service (pages 19, 20) recognized seventeen subdivisions, of which ten relate to the specific requirements of the given propositions and seven to acquisition of the site finally chosen as best suited to the circumstances of the undertaking and the final definition of all building and equipment features. These sub-heads will be discussed in order.

While it is clear that each of them has a bearing upon the building of industrial plants, irrespective of the nature of their output, it must not be overlooked that their relative importance is governed wholly by the purpose and conditions of each particular business that is taken under consideration, and the governing factor in one case will assume only a minor part in another.

In one business the governing motive may be publicity, and the need of effecting economies in processes of manufacture may be unimportant, as is illustrated by certain of the patent-medicine companies. In another case the advertising problem may be automatically solved through the attainment of a product of the highest standard, as is exemplified by the business built up by the Herreshoff Manufacturing Company, designers and builders of boats, and the work conducted some years ago by Alvan Clark, whose telescope lenses were of such superlative worth that they were sought from all parts of the world. In these instances everything is sacrificed to quality and a standard of product is attained that practically eliminates competition. The majority of industrial plants, however, are supplying to the market articles subject to close competition, and quality of output, economy of manufacture, and sales effort are matters of almost equal consequence. This phase of the subject should be constantly in mind during the explanation that follows, for it cannot be emphasized sufficiently except by taking up the detail consideration presented by a given industrial plant.

P-a. Determination of the specific manufacturing requirements and compilation of data relating to present and future needs.

It has been stated that new buildings and machinery for indusrial purposes, if extensive in character, are almost always provided for those who are already engaged in the line of business that is to be accommodated, so that the preliminary work commences with a study of the existing methods and facilities and a knowledge of the purposes that have prompted the building work.

It can be properly assumed that the fundamental reason for a given organization being engaged in a certain business is the familiarity of its members with the requirements of the trade supplied. Such knowledge is the main asset of those engaged in industrial work, so that they are necessarily best able to define just what the plant is to manufacture and what its output shall be. Therefore, the industrial engineer must look to his principals for advice in this regard.

Every large business has one or more men who devote all or part of their time to the study of the principal matters coming under the first heading of "preliminary service"; and changes in processes, the installation of new equipment or apparatus, and the rearrangement of machinery or departments are constantly going on. The articles composing a large part of this Magazine's publications bear witness to the enormous amount of investigation and planning that is necessary to keep abreast of the times in even a comparatively narrow field of industrial work.

The selection of equipment types and processes is obviously at the root of economical production, so constant study must be made of these subjects to keep reasonably up to date. Betterment of methods usually is attained only after much time and money have been expended, and it is manifestly the province of those who are directly engaged in a given business to institute research work of this character. The development of methods and processes incident to the manufacture of almost any line of output illustrates the condition to which attention has just been directed. For example, the present method of forming the felt body of the Derby hat, or the process now used in making the printer's matrix, or the determination of the composition and treatment of steel for an efficient automobile spring, have been brought to their present high efficiency only after years of painstaking work, and further advances will undoubtedly come slowly and are likely to entail large expenditures.

Obviously the services of the industrial engineer should not be expected to contribute materially to these fundamental industrial problems which are special to each individual industry. They comprise that part of the knowledge needed when building new plants which must, in the majority of cases, be contributed by those directly identified with the business for which provision is to be made. But the industrial engineer must thoroughly familiarize himself with the machinery, methods, and processes in use in the existing plant, for it is this information which will form the basis for his subsequent work. It is of the utmost importance during this period —and, in fact, throughout the time that he is engaged upon the work—that the enginer be accorded the full co-operation of the owner and his people, although he should be expected to take the initiative. This is a matter that is of equal importance to both parties, for while the industrial engineer needs the advice of his principals, the latter should be conversant with the work he is doing, especially after the preparation of departmental and building layouts has been commenced. It is always easier to secure the approval of a given plan by discussing it from time to time as the work goes forward, and when this is done the anticipated efficiency of the completed plant is much more likely to be attained, as the purpose of the various provisions that have been made is properly understood in advance.

The preliminary investigations of the engineer will, however, cover a great many matters concerning which his principals have little or no reliable knowledge. These comprise the factors which, in a certain sense, are incidental to the specific manufacturing work, such as the power and lighting requirements, heating and ventilating requirements, sanitary requirements, care of employees, and the requirements imposed upon the building structures by the work in question. With the possible exception of the power and lighting problems, these matters are in the majority of cases only partially understood by those who manage industrial plants, and we should not expect to find it otherwise.

Throughout the period when the foregoing subjects are under investigation the engineer should make complete and systematic notes, and in many cases the data that he secures can be advantageously reduced to unit bases —such as the floor area per operator in different departments, or the floor area per ton of finished product, the power consumption per square foot of floor area needed for artificial lighting and, in some cases, for power in different departments, and so on. It is in regard to details of this kind that the competent industrial engineer has a great advantage over men who are not constantly engaged in this field of work, for he adheres to a definite plan of procedure that has been ascertained after repeated modification and amplification, so that each factor is taken up in its proper sequence and no important detail is overlooked.

P-b. Determination of fundamental principles that will be followed in the new plant regarding the administration of all manufacturing details.

The engineer must have, in addition to the information just covered, complete notes concerning the plan that will be followed in the finished plant for the administration of manufacturing work, for this is a matter that may have a very decided influence upon the arrangement of machinery and departments, and it is the basis for arriving at an office layout, including the clerical offices located throughout the shops. Therefore it is necessary for the engineer to be conversant with the fundamental principles entering into the different systems of shop management, if for no other purpose than to know how to provide properly for the system that is prescribed.

In order to illustrate this point attention is called to the fact that the selection of machine-tool equipment for a metal-working plant employing a system of administration such as is advocated by Mr. Fred W. Taylor, would prove to be quite a different problem from that which would be offered if the machines were installed where no instruction cards were issued and the men were guided almost entirely by their own experience.

Not infrequently the industrial engineer is able to designate to his principal with such clearness the advantage that would accrue through a modification in his system of management, that the latter will adopt his recommendation and agree to have the physical layout prepared in accordance therewith. For example, a system requiring a doublebin storeroom necessitates that considerably more floor space be given up to this department than would be the case if single bins were used. If the former plan is desirable, it is quite important that this decision should be reached at he commencement of the work. The tool-room system that is to be followed in a large metal-working establishment must be considered when making the individual department layouts, if the best results are to follow, and the system of checking employees in and out of industrial plants is a determining factor when providing entrances and exits.

Occasionally the owner desires a certain amount of latitude provided in the layout, so that he may be able to depart in certain particulars 'from the prescribed plan. The extent to which this is possible depends almost entirely upon the character of the output. A great deal of industrial work is performed upon machines, or necessitates the use of processes, which can readily be housed in standard factory buildings that need not be designed with particular reference to the requirements of isolated departments, whereas in other cases the buildings must be wholly special in character, and to a certain extent should be considered as a part of the necessary equipment.

P-c. Consideration of features exemplified by plants recently built for essentially the same class of work.

The information secured under the headings P-a and P-b, after being recorded, forms the basis for the layout of the new plant or extension, but it should be supplemented with general data concerning the practices that have been followed by others when building plants for essentially the same class of work.

It is in this regard especially that the services of a properly equipped engineering organization should come prominently into play, for in addition to their own experience they should have for reference a complete statistical department where the desired facts could be readily obtained. Reference should not be made to these records until the owner's practices and views are fully understood, and in any case much care must be exercised in the selection of features that have been adopted by other concerns, because they have been frequently dictated by special requirements that are not evidenced during a casual inspection.

P-d. Determination of kind and amount of machinery that should be provided for immediately.

The machine equipment and apparatus for process work should now be decided upon. In most instances the list comprises a certain amount of machinery formerly used elsewhere, together with additional equipment which may be for the purpose of increasing the output or for the greater efficiency made possible through its use. The probable equipment requirements for the future should also be approximated, as this governs the amount of floor space that it should be possible to secure by further extensions. The owner and engineer are frequently confronted with the need of providing equipment for the manufacture of certain articles in large quantities, which had been turned out previously only in small lots. In such case, after the output of a given type of machine had been ascertained the cost of operation must be carefully figured, taking into account all fixed charges. Other available types of machines should be considered in the same manner, but as was previously stated matters of this kind are usually worked out by the owner prior to beginning work bearing upon additional accommodations and facilities.

Sometimes complete freedom of choice is permissible when determining the machinery or processes that shall be used, whereas under other circumstances collateral conditions must be taken into account. I have in mind a certain industry where the labor union dominates its members to such an extent that for the present, at least, they are successful in prohibiting the use of particular machines, or if they are used, the rate of wages per piece must be substantially the same as for performing the work in accord with older methods.

The point has now been reached when the department layouts can be worked up as a preliminary step leading directly to the arrangement of departments within given buildings and the determination of building types. When this has been done the necessary property area can be arrived at, the site selected, and the final grouping of buildings decided upon. The results of the investigation of the kind and amount of machinery that should be provided for, as well as the requirements of the special or process work imposed by the business, should now be carefully tabulated, and time can be greatly economized and more complete data secured through the use of standard forms drawn up for the purpose. Much of this body of data is fixed in character; for example, the weights and dimensions of the largest articles that are handled directly govern the floor loads, overhead room, door openings, and crane requirements that should be provided for in the building designs, whereas such unit figures as the floor space per operator in different departments, or the handling cost per unit of output, or the current consumption for artificial lighting per square foot of floor area, frequently show the necessity for modification of the preliminary outlines prior to their adoption as a basis for the work that follows.

Then, again, a study of certain of these statistics will often result in the discovery of inefficient performances in specific operations, and means for their correction can be provided in the new layout. The analysis of certain cost data, particularly those which have to do with the handling of materials or partially finished articles, is important, as the economies which should follow the provision of facilities other than those in use can be ascertained only with such information at hand.

P-e. Determination of geographical location of site and whether plant should be built in business centre or suburban section.

Additions to existing plants as a rule are provided either upon property already owned, or on an adjoining site that can be acquired. At times, however, it is decided to build an entirely new plant, and complete freedom of choice may be permissible. If this is the case, after the engineer has proceeded thus far, he can intelligently discuss with the owner the question of geographical location. The governing factors are usually the raw-material market, the logical point for the distribution of sales, the labor market, and certain broad matters of business policy. It will not be necessary to elaborate these factors further than to say that it must be borne in mind that certain businesses will show a good profit only if investment charges are curtailed to a minimum through the purchase of an inexpensive site and the adoption of buildings of the utmost simplicity; whereas in other cases much more permanent and ornate structures, located directly in a business centre, may be permissible or even desirable on account of the advantages from the standpoints of economy and publicity gained through intimate contact with the market. The character of competing plants must always be taken into account, as sales prices are governed largely by rates at which other companies can market their goods at a profit, and these rates are dependent partially upon the investment charges.

Usually a number of locations are taken under consideration and final judgment is deferred until the negotiations for a specific property can be undertaken.

P-f. Determination of approximate arrangement of equipment and processes, based upon elemental routing and administration requirements.

The character of the locality in which the plant is to be built has a very decided influence upon the layout of departments and the character of the buildings, as it largely governs the necessity of multiple-story structures. Since a decision has been reached in this regard, the work can proceed with the arrangement of the machinery and processes that have been selected previously for the performance of the industrial work. In the first instance, this matter should be considered wholly aside from any preconceived opinions (other than those of the broadest character) regarding building types. Usually the industrial engineer can assist very materially in this work, as the arrangement of machinery and the inter-relationship of departments are governed by broad principles which are common to industrial work of all kinds. A theoretical arrangement of machinery should first be made, with a view to minimizing the travel of the parts or materials upon which work is to be done when passing from the state in which they are received to a point where they are finished and ready for assembling and shipment.

The most satisfactory method to follow is to make accurate templets of the various machines or the spaces required for manufacturing or process work. In the first instance the outline of each templet should indicate the over-all dimensions of the machine or piece of apparatus, and if these are greater than the foundation dimensions, the latter should be indicated by lines drawn within the limits of the templet itself. Consideration must be given, as suggested above, to the necessary working space about each machine. The main relationships of various templets are dictated by the conclusions that have already been reached concerning the general plan of manufacture that is to be adopted, but usually a number of alternate layouts differing in detail will suggest themselves.

In certain cases the routing problem is comparatively simple and dictated requirements can be very satisfactorily met. The arrangement of machinery in a factory for the manufacture of Derby hats illustrates this condition. The raw material consists principally of rabbit fur, which, after being properly cleaned, is passed through a machine called a "former." The conically shaped product resulting is then passed through some thirty processes that gradually mold these cones until they only require the addition of trimmings to make them complete hats. It will be seen that the hats comprise essentially but one piece at an early stage of the process, and the path that they follow can be readily plotted in a manner that will comply with the requirements of minimum handling. This condition also lends itself to the ready satisfaction of a fundamental principle underlying the management of men—namely, that they should ever feel the pressure of work yet to be done and their inability to quite meet the demand ahead of them. This is brought about through the fact that the partially finished hats are passed from process to process in specially designed racks, and as the operators can plainly see the product they have to draw on, an incentive can readily be created whereby each man tries to get done with the work behind him and overload the next operator.

In comparison with the illustration just cited, consider the routing problem that presents itself in laying out a plant for the manufacture of automobiles. Several thousand parts enter into a completed touring car. Many of these require the same classes of equipment for their manufacture, and it is not possible to arrive at machinery and department layouts that do more than meet with a fair degree of efficiency the broad requirements presented by the production as a whole. The routing of individual pieces in many cases will prove very unsatisfactory, but such sacrifice must be made in order to arrive at the best compromise. I wish to dwell particularly on this word "compromise"—the term which must be applied to so many industrial-engineering conclusions.

As a rule, there are such a multitude of factors to be taken into account that it is impossible to arrive at a solution which will meet each of the individual requirements in more than a partially satisfactory way, although the result as a whole may be substantially the best that can be obtained.

The engineer who is well versed in the work incident to the arrangement of equipment and departments in industrial plants realizes to how small an extent he can rely upon any established rules or data and his initiative and common sense must be counted upon to bring a working result from a mass of what often appear to be conflicting conditions where no logical relation can be traced.

P-g. Determination of floor areas required for manufacturing departments, storage departments, assembling departments, offices, etc.; also for probable future requirements.

Having arrived at the arrangement of machinery and apparatus required for process or other special work that will result in a minimum charge for handling of product, it is necessary to decide upon the space that must be provided around each machine or process for the storage of partially finished product.

When the product passes automatically from machine to machine, it is impossible for congestion to occur, so this question is easily solved; but in a majority of cases the performance of a specific manufacturing operation upon available pieces is only indirectly dependent upon machinery other than that required for the purpose of the operation in question. That is, the work is not continuous; there will be certain pieces or materials upon which work is yet to be done, others that are completed insofar as the machine in question is concerned, but that must be stored pending the time when they will be removed to the next operation. When calculating the space required for this storage it is necessary to determine the best method of stacking the product; that is, whether it should be piled on the floor adjoining the machine, or in boxes or special appliances designed for the purpose; also whether the material in question can be moved by hand or must be handled with power. After approximating the area required for machines and storage of parts during transit, the areas needed for passages, general storage departments, special enclosures (such as inspection and tool rooms) must be calculated and the results incorporated in the final provisions.

P-h. Determination of the departments which *must* be accommodated on the ground level and which *may* go on upper floors.

We have settled, so far, only the sequence and general arrangement of machinery and processes and an allotment of space considered as a whole, but no decision has been reached concerning the definite manner in which the area should be housed. It is always desirable to. perform certain kinds of work upon a first floor; for example, where the machinery is very heavy and must be supported upon substantial foundations, or where a large amount of overhead room is required for crane service, or where certain process work makes it desirable to have direct overhead ventilation, as may be the case where large furnaces are installed. This, however, cannot be settled wholly from the standpoint of manufacturing requirements. It has been mentioned that the value of the real estate must be considered, and if this is excessive it may be necessary, or at least desirable, to put on second or third floors departments which, under other conditions, would be kept on the ground level. Therefore, it is necessary to estimate the cost of the real estate, but this can be done with reasonable accuracy as decision has already been reached as to the probable geographical location and character of locality desired. The results of this part of the work largely govern decision as to building types and construction details.

P-i. Determination of railroad and trucking facilities that should be available for receipt and shipment of materials.

The necessary railroad or trucking facilities, or both, required in connection with the receipt of product entering into manufacture and for the shipment of finished goods, have already been preliminarily considered; but these matters must now be taken up in detail, for they have a decided bearing upon the selection of the building site. The desirability of having direct communication with more than one trunk line, the permissible radii of curves, the length of track required and the number of sidings into which it should be divided in order to curtail demurrage and otherwise to facilitate the operation of the work must, therefore, be ascertained before final decision upon the site is made.

P-j. Determination of total property area needed at once and amount that should be reserved for the future.

A tabulation should now be made of the areas necessary for different classes of work, for storage, and for all other purposes including yard requirements, the immediate and future needs being segregated. The open and enclosed areas should be totaled separately, and a note made of the enclosed floor space that does not necessarily have to be upon the ground floor. With all the foregoing data at hand, a fair opinion can be reached concerning the shape of property that should prove most desirable.

Chapter III

SELECTION OF THE SITE AND DEFINITION OF THE BUILDING AND EQUIPMENT FEATURES

THE considerations have so far been based upon the assumption that an ideal property can be had; and this is as it should be, for the site should be selected with a view to attaining as nearly as possible to such an arrangement. Of course, the procedure is somewhat different if the location of the new plant is fixed in advance, as actual conditions must then be taken into account from the start with a view to minimizing apparent disadvantages. The remaining subdivisions of our preliminary service have to deal with the selection of the property finally determined to be most suited to our circumstances, and the final disposition of the building and equipment features. These subdivisions will be taken up in detail in the present chapter.

P-k. Selection of property that most nearly meets the requirements dictated by study of the foregoing factors. If possible, it is preferable to defer purchase until completion of preliminary work.

Usually a number of sites are found to possess certain of the essential requisites, although each may fail to comply in some particular with the ascertained requirements. Consequently, several properties are frequently taken under consideration pending the completion of definite layouts, building sketches, and estimates of total cost.

In order to make the best selection of property for an industrial plant, all the data bearing directly upon the desirability of the location for the business in question should be separately tabulated, and in this way the work will be greatly simplified through the ready elimination of undesirable sites. The essential data will, in most cases, comprise a knowledge of the character of soil for foundation purposes, expense that will be incurred to make the property available, cost of property, availability of water, coal, oil, gas or other raw materials, sewers, and protection afforded by the locality against destructive fires, etc. It has been assumed that the decision previously reached as to geographical location has been based upon a knowledge of the desirability of the labor market, and the point best suited for the economical receipt of the materials or products upon which work is to be done and their final distribution to customers, and, of course, only such properties would be considered as afforded the requisite area.

If one property appears to be undoubtedly preferable to all others, the engineer can then proceed accordingly; but as has been stated, it is possible that he may wish to work up preliminary layouts for several properties before making the final selection. In this case, precise information should be secured concerning each site that is to be taken under serious consideration. First a survey should be made, preferably by engineers in the employ of the municipality or county in which the site is located, for their intimate acquaintance with the status of local surveys, deeds, and records is valuable. The "plat," as a survey is called, should give the property limits and elevations (at the intersection of suitable cross-section lines) which should preferably refer to established datum. The location and character of all buildings, or other structures, and railroad sidings existing on the property, should be carefully recorded, as well as conditions of this character in connection with the abutting properties.

All sewers, gas pipes, and water pipes and openings to same, as well as all electric circuits (both overhead and underground) occupying the adjoining streets or crossing the property, should be indicated and their depth or height above the standard datum noted. The same plat should indicate the location of such test pits as are made in order to determine the character of the soil or wells that have been driven to ascertain the available water supply, and a note should be included calling attention to adjoining streams, if any exist, and to the nearest trolley system or railroad, if sidings are not available upon the property.

Frequently, a considerable part of this information cannot be recorded upon the plat itself; but, in such cases, reference should be made to the source where it can be had. The engineer's work is greatly facilitated if thorough information in regard to the matter just touched upon is promptly secured and properly recorded.

P-1. Preparation of alternate layouts of departments, segregating them into one or more buildings of assumed types, taking into account all the foregoing factors, including the selected property.

We are now in a position to decide to how great an extent the different departments should be individually housed or shut off from each other; that is, how the total floor area should be divided between separate buildings, and the given buildings into distinct units.

Obviously, it would be inconsistent to have a saw mill in the same room or enclosure with departments for shellacking and final finishing of wood surfaces, as good work of this character cannot be performed where the surrounding air is carrying even a small amount of dirt or grit. For the same reason, a gray-iron foundry should be separated from a machine shop in which delicate or accurate work must be done.

In contrast to the illustrations just cited, there are many other instances where it is much more difficult to decide whether or not the departments should be separately housed.

In certain localities it is not feasible to have union and non-union men working side-by-side in the same shop unless their work falls under widely separate heads. This is occasioned by the fact that at times union men positively refuse to work when non-union men are engaged in their midst. Many types of machinery, however, can be properly and economically operated by comparatively unskilled labor, but to permit this it becomes necessary to meet the limitations imposed by the labor unions by housing such equipment in separate buildings.

It must ever be borne in mind that in connection with all, or practically all, the matters that we are discussing there is a very great deal of room for difference of opinion among those who are working together, so that it is always necessary for the engineer to have a good and sufficient reason to support each of his recommendations; and in many cases, after the problem has been discussed between client and engineer, a modified plan is adopted, emphasizing again the need of complete co-operation upon the part of all interested in a project of this character.

We have now reached the point where preliminary sketches can be made of the buildings, and if all the information covered by the foregoing headings has been systematically tabulated, this resolves itself into a comparatively simple matter. The information in question dictates, as it were, the places where the building structure must not trespass, so that the design of a building to conform with all the industrial requirements must be such that the work can go forward with practically as much freedom as though the building did not exist at all; that is, the workers, whether employed at individual machines or engaged in moving material from point to point, should, to all intents and purposes, be unconscious of the existence of the housing structure. If this is not the case, the buildings become a constant hindrance to the efficient performance of the industrial work, which will be evidenced through inefficient departmental arrangements and the existence of structural details that interfere with the most economical manufacturing performance.

Possibly a crude illustration will serve to emphasize this point. We will assume that it has been decided to build an enclosed oval track for bicycle races, and that those who are behind the proposition, being familiar with the proper plan to follow, engage a person who makes a specialty of the building of race tracks proper. We will compare the result that should be secured in this case with what would probably follow had they first employed an architect to design the building in which a track was to be built. In the first instance, after carefully selecting the site, the race track would be built in the open, and the only consideration would be to provide an oval that from every standpoint would lend itself to the attainment of the highest racing speed with the greatest degree of safety. After the accomplishment of this end, it would be a comparatively simple matter to design a building that would completely house the track without interfering in the slightest way with the performance of the riders. In the second instance, while the requirements of a high-speed race track would no doubt be taken into account to a certain extent by the architect, it is more than likely that after the work was completed certain difficulties would develop. For example, it might be found that the track could not be banked at the corners quite as much as it should be, owing to the fact that a row of side windows of a continuous height around the building prevented such a course.

Again, the widening of the track at the curves might be interfered with through the location of one or more columns that had been placed without knowledge of the fine points of race-track requirements, such as the plan used by contestants for passing each other at the curves. Just as the governing factor in the solution of the illustration cited above is simply a routing proposition, so it is also of great importance in regard to the determination of the character and sizes of buildings for industrial purposes; but this, of course, does not apply to the selection of building types—that is, the kind of structure that should be adopted.

The decision whether the buildings should be of reinforced concrete, or of mill construction, or steel-frame, rests in part upon the specific requirements dictated by the manufacturing work that is to be performed within them and upon certain requirements incidental to this work, such as climatic conditions, provision for protection against fire, the character of locality in which the buildings are to be erected, etc. Not infrequently the various buildings composing a large plant can be constructed of different materials, without militating against the efficiency of the plant as a whole, either from the standpoint of fire hazard or industrial requirements, and by so doing the expenditure necessary for this part of the plant may be minimized.

Many illustrations could be cited to show the influence that the manufacturing work may have upon the building types, and on this account it is necessary that the industrial engineer should be quite as conversant with the characteristics of the various types of construction that are in use, as he must be with the requirements arising through the conduct of the business that is to be housed. The absence of vibration in a properly-designed, reinforced-concrete building, where high-speed machinery has been installed, makes the system preferable for such purposes, etc.

It must always be borne in mind that the nature of the contents of an industrial plant, and the fire hazard presented by outside conditions, are the governing factors in connection with the selection of the type of building construction best suited to comply with the requirements of fire protection. In some cases the adoption of reinforced concrete eliminates the need of a sprinkler system, although usually this is not so. A properly designed building of mill construction, if protected with sprinklers, fire-fighting apparatus and cut-off walls, is in many cases as reliable as industrial conditions demand.

The question of appearance of buildings has been previously touched upon, and where an attractive plant is desired the character of the buildings that should be located upon the front of the property must be selected with this requirement in mind. In most cases there is a logical front to a building site dependent upon the layout of streets, railroad facilities, railroad stations, and street-car lines.

P-m. Reconsideration of all work done so far and preparation of a revised layout incorporating, as far as possible, the best features of the various preliminary studies. Making outline drawings of buildings.

The time has now arrived when the final block plan or property layout can be prepared, and as a number of alternate schemes will probably have been suggested, it is necessary to make every effort to incorporate the good features of each of these in the final plan. By this time there is not likely to be much doubt as to which property, among those under consideration, is most desirable, all things considered, so that the block plan now referred to must be accurate and final in every particular.

Previous consideration will have been given to the question of railroad facilities, but now the approval of the plans by the trunk-line railroad upon which the property is located must be secured, and all other questions relating to the site that may have been settled in only a tentative manner must be defined beyond any misunderstanding.

Following the completion of the final block plan, accurate outline drawings must be made, illustrating all the principal characteristics and giving the essential dimensions of the various buildings, or enclosures, required. These drawings are necessary both in connection with the preparation of the estimate of cost and for the purpose of making clear to the owner the exact character of plan that is recommended. If the plant is of considerable size, it is also desirable to prepare a large perspective drawing showing the layout as a whole.

P-n. Preparation of a classified estimate of cost based upon unit prices.

An estimate of cost must now be made, covering the expenditure necessary in order to carry out the entire work contemplated by the drawings and notes recorded during the performance of the work that has gone before. This estimate should be classified so that the costs of the principal items entering into the layout can be considered separately. As a matter of fact, such an estimate should be based upon the unit-cost figures, for the plans and specifications should not as yet have been carried to the point where the actual quantities of materials can be ascertained and the amount of labor estimated. An important part of the data carried in the records of engineering organizations which specialize upon industrial work has to do with such unit costs, and if proper discretion is exercised in its use the total figures arrived at are usually found to check closely with the actual expenditures incurred.

The cost of multiple-story reinforced-concrete buildings can be estimated with reasonable accuracy upon a basis of so much per cubic foot, depending upon the floor loading, general character of the building, etc. The cost of heating by direct radiation can be estimated upon the basis of so much per square foot of radiation, depending upon the temperature desired, the locality of the plant, the character of the building, etc. Many other important items of expense can be readily worked up in the same manner, although it is, of course, necessary to secure definite lump-sum figures upon all special equipment or unusual provisions entering into the plant.

P-o. Determination whether estimated expenditures would result in a "fixed charge" consistent with the probable profits of the business; i. e., can the business carry the necessary investment.

The estimate should now be presented to the owner, who, with the engineer in consultation, should decide whether the expenditures required will result in interest and depreciation charges that are greater than the business can properly stand. Very frequently decision in this regard must rest upon the broad judgment of the owner, rather than upon definite figures arrived at through preparation of detail estimates of operating expenses. If it is decided that the expenditure is excessive, after taking into account all probable advantages that it would provide, the plan must be consistently modified with a view to curtailing the first cost. It is impossible to lay down any definite rule for accomplishing this, for every commission presents somewhat different conditions; but the engineer should by this time have gained an insight into the entire problem that will enable him to decide with reasonable promptness where the necessary economies can be effected.

P-p. Determination whether owner is prepared to make the total justifiable expenditure.

Not infrequently the owner may not be prepared to make the requisite expenditure, even though conditions may indicate that they are entirely warranted; and if this is the case, it is very necessary that the engineer should take a firm stand in regard to the policy that should be followed, for only too often the value that should accrue from the preliminary investigations is in a large measure lost through too hasty a readjustment of the plan. The engineer, of course, must co-operate with his principal to the fullest extent, recognizing the need of keeping well within the funds that can be surely counted upon as available for the work. He must remember that successful concerns are constantly extending and developing, and that the purpose of the preliminary study is primarily to arrive at a plan of development that can be followed out either to the full extent warranted by business conditions, or to the limit of the available resources of those who have in hand the business in question.

P-q. Revision of layouts, if required by financial limitations (P-o or P-p or both), and placing data and plans in suitable form to be used as a basis for the preparation of architectural and engineering drawings and specifications.

If the owner decides that he cannot build to the extent that the approved estimate requires, it is necessary that the engineer should be especially firm in his stand for a proper disbursement of whatever money is spent, for particularly at this time he must guard against assenting, through pressure that may be brought to bear by the owner, to a plan of procedure that would militate seriously against ultimate plant efficiency.

The result of the foregoing preliminary work should be an approved layout of buildings upon the property, the exact definition of such matters as service and manufacturing equipment, railroad facilities, building types and sizes, etc., and it remains as a final step only to tabulate all the data and to prepare such further sketches as may be required as a basis for the preparation of the detail plans and specifications for the architectural and engineering features. This brings us to the second broad heading of the classification of work incident to industrial construction.

In concluding what has been said regarding the preliminary work, I wish to repeat that as a rule the principal questions at issue demand for their solution only a moderate amount of originality upon the part of the engineer in direct charge of the work, whereas his intimacy with what has already been done, coupled with his ability to co-operate with others and to arrive at sound conclusions after the facts have been ascertained, in a large measure govern his success. The faculty of observation, together with a mind that will unconsciously analyze reasons for conditions with which it comes in contact, are a necessary part of his equipment. The effort should, of course, be made to solve each operation in a more efficient manner than had previously been done, but little progress will be made except by those who profit to the fullest extent by past performance in the same field of activity.

Chapter IV

DETAIL PLANS AND SPECIFICATIONS

IT will be assumed in connection with all that follows that the preliminary work has been properly completed, resulting in an exact definition as to the entire physical requirements of the plant, so that the work under this heading resolves itself mainly into the selection of such standard apparatus and construction appliances as will most efficiently meet the specified needs, and the preparation of detail plans for the buildings and for special features that cannot be secured in the open market and must, therefore, be built to order. In either instance, the character of the equipment, materials, or work required is defined through the medium of drawings and specifications, and the efficiency with which the requirements are met depends principally upon the manner in which these are prepared and the purchasing negotiations conducted. As the procedure varies considerably, depending upon the particular feature of the plant that is under consideration, the subject will be considered briefly under each of the sub-divisions that were enumerated in the first chapter.

D-a. Preparation of plans and specifications for special machinery as defined by preliminary work.

As this sub-heading relates specifically to special machinery, the drawings and specifications prepared, in order to assure the provision of suitable apparatus, must be in much more detail than is necessary when the conditions can be fulfilled by standard equipment. No fixed rule can, however, be laid down as a guide, for in some cases an exact definition of the work that is to be accomplished and a general description of the characteristics of the machine that is needed, are all the data that it is desirable to place in the hands of those competent to submit bids, whereas in other instances detail designs should be fully worked out, thus relieving the builder of all responsibility other than that pertaining to a strict compliance with the drawings and specifications. Special apparatus of this character is usually provided for directly by the owner, as his experience should qualify him in such special matters to an extent that would hardly be possible with the engineers.

D-b. Preparation of plans and specifications for all other industrial physical features defined by the preliminary work.

This sub-heading pertains to all equipment and apparatus required directly in connection with manufacturing or process work other than the special machinery just mentioned. The majority of industrial companies depend for the performance of the greater part of their work upon standard equipment and apparatus that is built for the trade, and the mistake is often made of believing that the selection of equipment of this character is a comparatively simple matter and does not require the consideration that should be given to the more special features. As a matter of fact there are available for most trades so many different makes and types of apparatus designed for the performance of essentially the same work that it is by no means a simple matter to select the particular equipment best suited to a given purpose. In the machine-tool business, for example, manufacturers of engine lathes, boring mills, milling machines, drilling machines, etc., have designed their particular output for the performance of work coming within certain well-defined limits as to size, accuracy, and speed of operation, and the existing differences must all be taken into careful account when purchasing machine tools for a given business. As the leading machine-tool builders have established their reputations through their ability to carry out their guarantees, it is sufficient when soliciting bids to forward to them a concise statement of the character of work that is to be done, and to ask that complete data be submitted as to the details of the machine recommended and the rapidity with which the operations can be performed. There are, of course, certain matters concerning which machine-tool builders should be posted, such as the system of motor drive that is desired if the machine is to be electrically equipped, the kind of tool-steel that is in use, and any other features bearing on the machines' operation that have been standardized for the shop in question. A careful comparison of the information returned with the bids will promptly reveal the detail features in which they differ; and this understanding, coupled with a knowledge as to the performance of the machines in other plants, forms the basis for final judgment.

This method applies generally to the purchase of wood-working machinery, textile machinery, cement-making machinery, and all other standard types of manufacturing equipment. Such equipment is usually purchased by those who will have to do with its operation after the plant is completed, although occasionally engineering organizations are engaged to handle this work.

D-c. Preparation of plans and specifications for power generation, transmission, and driving equipment to meet the established requirements.

The principal work in connection with the selection of this equipment is completed when the plant requirements have been fully defined. As this is a matter that was touched upon in a previous section it need not be dealt with here. A decision having been reached as to size of power units that will be required, the kind of current needed for power and lighting purposes, etc., it is necessary to figure out carefully, unless the data are already available, the cost of power-plant operation based upon the installation of the various types of apparatus that are available.

The determination of the character of the prime mover is followed by the choice, if steam is to be used, between turbines and reciprocating engines and, if the latter, between simple or compound, condensing or non-condensing.

Having narrowed down each other important feature in the same way, specifications should be drawn in such manner that while details such as ratio of heating surface to grate area, steam pressure, piston speed, current density of electrical conductors, etc., are all confined to limits that experience has proved to be satisfactory, yet detail restrictions should not be made that rule out the product of reliable companies which otherwise would fulfill the requirements.

There are certain features in connection with the power and driving equipment which, as a rule, must be designed before bids can be properly solicited. I have in mind principally the piping, wiring, switchboard, line shafting, and transmission equipment generally. It is in regard to these matters that adherence to a definite procedure is of special importance. The contractors for the piping and wiring and other items referred to will volunteer to submit their own designs, but this course should not be permitted as there will be no definite basis for comparison of bids, and the work will be done by parties who are not conversant with the operation of the whole, and under conditions which are not favorable to proper protection of the owner's interest. The conditions are quite the reverse of those existing in the machine-tool trade, for example. In the latter instance, not only does the acceptance of the builder's design permit of the purchase of a standard machine, but years of research and practical experience have enabled the leading machine-tool builders to attain a proficiency in matters of design that is wholly beyond any result that could be obtained by anyone not directly in the business. A piping layout, however, is a made-to-order proposition, differing totally in its nature from the illustration just cited, and its proper solution can be best worked out by an engineer specializing on steam installations.

D-d, e, f. Preparation of plans and specifications for equipment needed to provide artificial lighting, ventilating and heating, and sanitary arrangements needed to meet fixed requirements.

The same procedure that was outlined in

connection with the power plant, wiring, and piping work applies to the features included under these sub-headings. A certain amount of designing must in each case follow the decision as to the system or type of equipment that will be used, but the designing will have to do principally with broad considerations, such as the number and location of lighting fixtures, the amount, character and location of pipe coils or radiators, the size and location of ventilating fans, vacuum pumps, or other apparatus necessary to the proper fulfillment of these requirements. Minor details of construction should be left open to as great an extent as possible.

D-g. Preparation of plans and specifications for fire-prevention apparatus based upon the conditions established by the preliminary work.

During the course of the preliminary work decision will have been reached as to what provisions are to be made for fire prevention. This may be indirectly accomplished, in part, through the adoption of thoroughly fireproof structures and, in certain cases where the buildings house non-combustible contents, little or no fire-fighting apparatus need be installed. In the majority of cases, however, pressure lines must be provided for the distribution of water to suitably located outlets for hose connections and to sprinkling systems, and in such cases the standards established by the various insurance inspection bureaus and by the Associated Factory Mutual Insurance Company should be adopted as a guide when preparing plans and specifications. Here again the specifications that are sent out when soliciting bids should be sufficiently complete to assure a fixed basis for the comparison of quotations through a proper definition of the specific types of apparatus and details of construction that are particularly desired.

D-h. Preparation of plans and specifications for the complete building or buildings, so prepared as to harmonize with the plans and specifications covered by headings D-a to D-g inclusive, and to meet requirements defined by preliminary work.

The method of preparing the plans and specifications for the buildings depends, of course, to a considerable extent upon the type of construction that is adopted. Buildings, considered as a whole, are essentially a built-to-order proposition; but of course they must be designed with a view to utilizing, to as great an extent as conditions will permit, standard materials and such standard features as metal window frames, sash-operating devices, ventilators, skylights, post caps and hangers, etc. It may be that in time the buildings required to house industries of a certain character will be standardized, units being built for certain established outputs, but in the majority of cases the buildings will always be special for each business that is to be accommodated. Conditions cannot be otherwise until every detail entering into the internal arrangement of the buildings has been standardized. Owing to the multiplicity of factors that are involved, the room that exists for differences of opinion, and the range in the desires of owners as to capacity, this result, if ever accomplished, will be attainable only in certain businesses where the processes are clearly defined, such as cement plants, rolling mills, etc.

The cost incurred through the construction of "made-to-order buildings" compared with what it would be if they could be standardized is not, however, so much greater as might be supposed, as in any case it is necessary to construct each job separately at the location that has been selected; and if the plans and specifications are properly prepared for the various parts of the buildings that are bought wholly or partially assembled, such as the structural steel work, mill work, etc., the repetitive manufacturer will make the shop costs compare favorably. Building costs are, however, influenced to a much greater extent by the character of the plans and specifications than is generally supposed, and this is particularly true insofar as the actual field costs are concerned. Those familiar with the status of the various building trades that must be employed in conjunction with the erection of buildings realize fully the need of minimizing field work, on account of the high wages exacted; so they aim to have as much of the fabrication provided for prior to shipment as conditions will permit, and to use every means to economize field expense.

As a general proposition, complete plans and specifications covering all features entering into building structures should be prepared prior to soliciting bids; but this work must, of course, be done by men thoroughly conversant with all available standards and the usual practices adopted in shops which will be called upon to submit quotations on the work. The fact that these detail prices may be solicited by a general contractor rather than by those who prepare the plans has no material bearing upon the situation. It is particularly important that structural steel frames should be designed, insofar as size of the members and the character of the connections are concerned, before quotations are solicited, for it is only in this way that bids can be secured which can be properly compared, and a structure assured that will meet, in every particular, the multiplicity of industrial requirements. The same reasoning holds true in regard to all other features and, of course, in any case the effectiveness of the result is dependent upon the familiarity of the architects and engineers with the work in hand.

A somewhat special condition has arisen as a result of the rapid strides made by the reinforced-concrete systems for the construction of industrial buildings, and it is likely to be several years before an established basis of procedure can be definitely laid down. At present there are various systems of construction, each of which is advocated by one or more contractors, and many admirable examples of their work can be cited. In certain cases these systems are patented, in part at least, and the building of large reinforced-concrete structures has become established as a thorough specialty, for reasons which are too well understood to need repetition here. At the present stage of development it is undoubtedly desirable, at least in connection with structures of considerable magnitude, to prepare plans and specifications of such a nature that the reinforced-concrete specialists can bid upon their own detail design as worked up to meet the proposed conditions, submitting with their bid such data as may be necessary to enable a thorough understanding as to the details of the proposed system. If all of the specialists figured upon the same system, this course would not be desirable, and it is not unlikely that at no very distant date this result, with the exception of minor matters, will have been reached.

One of the advantages in handling the preliminary work in the thorough manner described is that the buildings can be designed with a full knowledge of all the more important industrial requirements, so avoiding subsequent alterations, cutting of pipe openings, drilling the reinforced concrete, etc.; but even when the preliminary work is properly conducted many of these details are likely to be overlooked unless the plans and specifications are prepared in accordance with a carefully arranged schedule.

D-i. Preparation of plans and specifications for yard provisions that must be made to meet fixed requirements.

It is almost always necessary, when building an industrial plant, to make certain installations in the yard area between or around the buildings, but insofar as this discussion is concerned, these matters are too intangible for detail consideration.

D-j. Preparation of contracts to accompany plans and specifications when soliciting bids, so drawn as to provide proper protection for both the owner and the contractor.

A separate chapter could well be written upon the subject covered by this sub-heading, for it is a very important matter to have the relations of owner and contractor not only clearly established insofar as the actual scope and character of the service is concerned, but to provide adequate protection to both parties in regard to the legal questions that may arise and that usually assume somewhat different aspects in different States or cities. When arrangements are being consummated for the performance of a large and complex piece of work, it is always desirable to have prepared a contract clearly defining the duties of the various parties and, while legal advice should be sought, it is important that the papers should be primarily drawn to define a mode of procedure which actual knowledge as to the work required dictates as being the most efficient one. A form of contract suitable for the erection of a reinforced-concrete building is wholly unadapated in many of its clauses to the purchase of most industrial or service equipment. Often a standard form of purchase order is all that is required when contracting for equipment or material entering into industrial operations, and the conduct of a large enterprise is greatly simplified when the awarding of contracts and purchasing of material is in the hands of parties whose judgment in regard to this and many other matters that arise is guided by a comprehensive experience gained through the repeated performance of such service. This question of the letting of contracts and providing of equipment and materials will be taken up in further detail in later chapters.

CHAPTER V

CONSTRUCTION WORK AND INSTALLATION OF EQUIPMENT

DURING the period when the detail plans and specifications are in course of preparation, a clear understanding should be reached between the owner and the engineering organization as to the procedure that will be followed in connection with the actual construction of the buildings and installation of equipment.

The customary method is to submit the plans and specifications for bids to responsible concerns who are in a position to handle the various classes of work, and when this plan is to be followed it is only necessary to determine what policy shall be adopted in regard to the letting of the work in either large or small units. Certain engineering companies organized to handle the preliminary and detail engineering work that have been described, have construction departments perfected with a view to taking direct charge of the erection of buildings and installation of equipment. When such a company is employed its construction organization offers a second method for the handling of this part of the work. Occasionally an owner decides to carry out through his own force the work illustrated and described by the engineers' plans and specifications, this being the third plan that is possible.

Owing to the widely diversified conditions incident to different industrial organizations and properties, each of the methods referred to can be advantageously adopted under different circumstances. There is no doubt, however, that the third plan, viz., the direct assumption by the owner of entire responsibility for the construction of the work, is becoming less frequent and is desirable only where the nature of the industry to be housed is such as to necessitate the maintenance of a construction force organized to handle work along essentially the same lines as that presented when building a new plant. The amount of work that has as yet been handled in accordance with the second method is comparatively small, although probably now amounting to several million dollars annually, as there are only a few organizations that are prepared to render jointly thorough engineering and construction service. There are many reasons, however, several of which will be pointed out later, that make it very desirable at times to place entire responsibility for the planning and building of industrial plants in a single company, so that there is no doubt that an increasing number of the competent engineering organizations will create construction departments, and ultimately it is not unlikely that industrial work through the building period will be divided about equally between operations that are let by contract and supervised by the engineers, and those that are handled in their entirety by engineering organizations having their own construction departments.

In order that the procedure in each case may be generally understood we will consider the subject under the six sub-divisions contained in the classification appearing in the first chapter.

I will first deal with the more familiar method of letting the work by contract, the supervision being exercised by the engineering organization which prepared the plans and specifications.

C-a. Selection of responsible concerns to bid upon plans and specifications and securing bids from such parties.

In the majority of cases, when new industrial plants or large extensions to existing properties are built, it is advisable to secure bids upon the complete building or buildings rather than separate bids on the various features of the structures such as the concrete work, steel work, brick work, and mill work. The reason for this is that the architect or engineer whose organization does not include a construction department, cannot be expected to be conversant with the problems that confront the general contractor, nor be responsible for matters the proper attention to which demands a totally different character of organization. It is, however, imperative, if an expeditious and economical result is to be secured, that responsibility for the building work as a whole should be centered in a single company.

One of the important functions performed by a competent engineering organization is the selection of responsible bidders for the buildings and other features of the plant, and while the owner's desire in this regard should be sought and carefully weighed, the owner should be careful not to influence his engineers to too great an extent unless quite certain of his ground. Repeated experience with many contracting firms of varied financial responsibilities, located possibly in widely different sections of the country, trains the engineer rapidly in the problem of making wise selections, and his grounds are often of so subtle a nature that it is difficult to satisfy his principals thoroughly as to the correctness of his judgment. This matter is one of the utmost importance, and the policy and procedure followed in regard to it by a given organization is a direct measure of their business ability and impartiality. It is not only eminently unfair to ask contractors or manufacturers to figure upon work when it is practically a foregone conclusion that it will not be awarded to them, but such methods (even if unconsciously sanctioned) soon result in a knowledge by those who bid that a strictly square deal is not always forthcoming, so they not only take little pains to figure closely, but sometimes intentionally submit high figures. Therefore, this must be taken into careful account by the owner when selecting his engineers. The engineering organization, on the other hand, should be equally firm, during their relations with their respective clients, and stand absolutely for a clean-cut policy that is as fair to those who bid upon the work as to the owner.

Occasionally it may be desirable to include, in the general contract, the service equipment, that is, the equipment required for lighting, heating, sanitation, water supply, fire protection, elevators, and any other apparatus required to make the building itself complete in all respects, irrespective of the special manufacturing apparatus. Usually, however, these features can be let more advantageously as separate units, for each of them is sufficiently definite to obviate the likelihood of either overlapping of work or failure to contract for all essential details. All that has been said previously in regard to the selection of bidders is particularly pertinent to the equipment features, although it must be understood that it is necessary in many instances to secure bids on apparatus of different types in order to obtain the manufacturers' guarantees as to performance, which data, along with the actual bids, form the basis for decision as to the particular equipment best suited to the conditions.

As an illustration, it is occasionally desirable to secure bids on both reciprocating engines and steam turbines, as rapidly changing conditions may make the use of data and bids previously secured an unsafe basis.

C-b. Tabulation of bids, conference with owner, followed by placing of contracts.

When asking for bids on a building or buildings, it is almost always desirable to require the bidders to present alternate figures covering certain features in which two or more different methods or types of apparatus should be considered, and also to have included unit prices covering such classes of work as footings, brick work, etc., so that charges or credits can be figured upon an agreed basis in event of modifications in the plans. Owners and engineers as well are prone to underestimate the amount of time that is required to prepare, intelligently and accurately, a bid relating to a considerable piece of work, including possibly a great number of alternate figures and unit prices, so that very frequently an insufficient amount of time is given for this purpose. It is obvious that bidders who are compelled to rush through their estimates will "play safe," and the resulting figures will be unduly high. This should be guarded against, especially in connection with all the more important negotiations.

It is equally important that time should be allowed for a careful tabulation of bids before any conclusions are drawn, for first impressions are almost always based on the main lump-sum figures, whereas very often a study of the tabulated data (including, in addition to the figures already referred to, time for completion, and, if the bids relate to equipment, efficiencies of operation and detail descriptions of construction features) prompts an entire rearrangement of the bidders insofar as the desirability of their proposals is concerned.

After the tabulated bids have been subjected to the proper study, the engineers not infrequently find it necessary to confer with the concerns that have submitted them, and the question of price should be carefully gone over, each bidder being given an equal opportunity to better his quotation, either in accordance with the original or modified specifications, as the case may be. The engineer then draws his own conclusions and confers with the owner, securing finally the authorization to close up the transaction.

So much for the various contracts considered individually. Considered jointly, however, it is evident that they bear an interrelation to each other in so far as construction and installation of equipment are concerned, that must be taken into careful account in order that the work may go forward uninterruptedly and without one contractor interfering with the work of another, or doing work which must at a later date be undone. In order to accomplish this a schedule must be prepared in advance, showing the order in which the contracts are to be let, unless the operation and incidental conditions are such that the soliciting of bids can be postponed until plans, specifications, and contracts are completed and can go out simultaneously.

C-c. Superintendence of building construction and yard work.

There is no period in connection with the building of industrial plants when strict attention to details and at the same time a broad grasp of the work as a whole is more imperative than when the field work is going forward. Much depends upon the foresight that is shown by the engineer in his selection of a superintendent of construction, although in the final analysis the policy must be dictated from the home office, where control must be centered. This is usually a particularly trying time for all concerned; for if it is a new industrial plant, or more especially an extension to an existing property, the owner is not only eager to have the work completed so that operations can be commenced, but only too often cannot resist the temptation to take a hand in the construction work. He cannot have a sufficiently comprehensive grasp of the problem to realize that in order to promote the work as a whole expeditiously, many minor conditions are bound to develop which, considered individually, may appear to have been unnecessary and wasteful. However, the very nature of construction work is such that the most the engineer can hope to do is to minimize minor troubles, and the owner must measure the success of the work by the final result. The locomotive engineer does not stop his train if his gauge glass is broken, but gets along with the gauge cocks on the water column until a suitable time to make repairs. The owner who endeavors to dictate during the construction period without having a proper grasp of the problem as a whole may readily delay the entire work, very much as would the inexperienced locomotive engineer who brings his train to a standstill in order to take care of a minor matter, attention to which should not interfere with the accomplishment of the principal object in view.

In the past the tendency among architects and engineers (and owners as well) has been too often to look upon contractors collectively and individually as parties whose interests are so diametrically opposed to those of the owner as to warrant an attitude of perpetual suspicion toward them, which the same architect or engineer would not countenance for a moment toward manufacturers of apparatus and materials. There are, of course, unscrupulous contractors, just as there are unscrupulous engineers and architects, and the contractor has conditions to contend with, owing to his financial requirements, that unfortunately have frequently prompted methods which should not be permitted. All these matters should be taken into account by the engineer prior to selecting his list of bidders, and thereafter in his business dealings he should recognize in the contractor to whom the buildings have been awarded a man confronted with problems, if not as technical as those with which he himself deals, yet much more subtle and requiring for their proper accomplishment forceful methods which would not be appropriate in the drawing room or the shops of an organized industry.

C-d. Superintendence of installation of "service equipment" and all standard and special machinery or appliances needed for industrial purposes.

Usually, if the plant is a large one, a superintendent of construction especially experienced in mechanical and electrical matters should be employed during the installation of the power-plant equipment and special machinery. Very frequently the engineer's recommendations in regard to equipment are accepted by the owner wholly upon the statements that have been made to him, and the best interests of all concerned can be assured only through the engineer taking the initiative in the starting up of such equipment, having demonstrators on hand if their presence is desirable and making such tests as are required in order to substantiate his original statements. The owner who contends that one superintendent of construction, with assistants of comparatively limited experience, can properly look after the buildings of a large industrial plant, argues directly against his own best interests.

C-c. Checking work as to quality and amount and approving invoices.

The checking of work as to quality and amount commences almost simultaneously with the field work, and must be provided for through a system of records and definite plans of procedure which experience will have indicated as desirable for the different sections of the operation. The plans and specifications must be in sufficient detail to enable the superintendent of construction to inspect decisively materials as they arrive, except where shop inspections or laboratory tests are required (illustrated by the inspections made at plants where steel is fabricated, or in laboratories where samples from each shipment of cement are forwarded for testing purposes). In such cases provision must, of course, be made for immediately notifying the superintendent of construction, through the home office, of the results that have been obtained.

Following the inspection of materials comes the inspection of work, and finally the inspection of performance where operating mechanisms are erected. The system at the home office must be such that all reports as they are received are properly filed with the contract or order to which they apply.

C-f. Certifying as to completion of contracts.

The engineer in charge of the work (who should preferably be the man in whose hands the chief engineer has placed the preparation of the plans and specifications) must co-operate with the superintendent of construction in the preparation of estimates as to the work completed in accordance with the terms of the various contracts and orders and, of course, all the records regarding receipt of materials, inspection, tests, etc., must be taken into account when certifying as to the payments that are due.

The foregoing covers the principal points upon which the success of a construction operation depends when the various features of the work are awarded to contractors, and the field work in all of its phases is directed by the engineer who prepared the plans and specifications. It will not be necessary to take up in the same detail the procedure that is desirable when the construction work is handled by the engineering organization that prepared the detail plans and specifications, as this would in part result in a repetition of what has already been said. It will be necessary, however, to compare the methods of compensation that are usual and desirable in the respective cases, and to define approximately the conditions under which the contract method or the handling of the work directly by the engineering organization works out most advantageously. After all, these are the two points in which the owner is most interested; and if those who are prepared to render both the engineering and construction service strictly limit themselves to one or both branches of the work, according as conditions may indicate to be best, the advantages that the assumption of the entire responsibilities offer will be emphasized and much more work will be done on this basis than at present.

In the first place it must be taken for granted that only such engineering organizations as have proved themselves competent to handle construction work will be considered, and, as a matter of fact, the issue is definitely presented only when the firm which has prepared the detail plans and specifications happens to have had this requisite experience.

The procedure in this case differs from that followed when the work is let by contract, in that the engineering organization, instead of sending the plans and specifications to construction companies, will have prepared in its own office accurate bills of material and secure first-hand competitive prices, many of which it is usually necessary to obtain in the market adjacent to the locality of the new plant. Schedules of all the bids are prepared, and on each important purchase the owner's approval should be secured before a contract or order is finally awarded. The question of order of work is of even more importance than when the engineer merely superintends the construction, for the manner in which every part of the work progresses depends in the final analysis upon the foresight displayed in anticipating requirements.

The man to whom the field work is delegated, is responsible for the employment, through his foreman, of all common and skilled labor, and the superintendence of the work becomes the function of a member of the engineering organization, preferably of the engineer who was in direct charge of the preparation of plans and specifications. This man will have taken an active part in the purchase of the principal materials and equipment entering into the operation, and consequently has an intimacy with the entire project that proves of the utmost value during his later service as superintendent. The engineering organization is, of course, responsible for providing the necessary construction equipment, and, in fact, assumes charge of the entire operation in its every aspect, for it is the advantage this condition offers that usually makes such an arrangement so desirable.

The only feasible bases upon which to remunerate an engineering organization for such service are a fixed fee or percentage of the actual cost, for the economies effected through the competitive purchase of all materials just at the time they are needed, directly from those who can quote the lowest prices, should accrue to the owner. As a matter of fact, the owner is, to all intents and purposes, handling his own construction work, having engaged for this purpose a corps of specialists much as he would engage experts in connection with the conduct of his own industrial work. The services rendered by the engineering organization should be considered in no wise less professional than the work previously performed by them, resulting in the plans and specifications.

The materials would be purchased, under such an arrangement, at quite as favorable terms as could be secured by a contractor, and an equally satisfactory basis arrived at concerning the employment of skilled and common labor. At the same time the actual assembling of these materials into the final structures and the installation of the equipment would be under the direct control of those who know the exact reason for the provision of every single feature; and their knowledge of future operating conditions enables them to exercise an intelligent discretion that should result in a more harmonious whole than could result solely through a literal adherence to the most elaborate specifications.

A great deal has been said in defense of both the "lump-sum" and "percentage" methods of handling construction work, and it is not proposed to enter into this discussion in these papers. It has been assumed, when discussing the plan of building industrial plants by contract, that the engineers would exercise conservative judgment as to the basis of compensating the various contractors. There are certain instances where the percentage or fixed-fee plan is the only one that is at all feasible, viz., where it is quite impossible to foresee with accuracy the conditions that will be encountered, or where speed is a matter of paramount importance. Then again, there are other conditions which as definitely call for the lump-sum basis. The conditions are radically different, however, when the construction work is handled by an engineering organization, for whatever advantages the lump-sum method may offer are outweighed by those resulting from the direct assumption of the owner's interests, secured through the fixed-fee or percentage plan.

When speed is of primary importance the work can often be greatly expedited by following the plan now in question, as certain features of the construction work can be commenced some time before the completion of the final plans and specifications. This method is always preferable where it is imperative that the owner should have direct control of the construction work, as when an extension is being built to an existing plant and the field work must be subordinated to the requirements of manufacture.

Before concluding these remarks regarding this method of procedure, attention should be directed to the necessity for thorough experience under just these conditions on the part of those who undertake this plan of work, for, unless this is the case, a situation may easily develop that results in losses far exceeding any advantages that may have been obtained. One of the first requisites is a system whereby the entire costs of the work will be properly classified and reported on cost sheets where an immediate comparison can be made with the original estimate that was approved by the owner. Statements should be presented to the owner monthly, showing the exact status of each subdivision of the work, giving the amount of the original estimate, the money that has been paid or is due for this same subdivision, and the obligation that may have been incurred but is not yet due.

Every change in the plans authorized by the owner, whether of minor or major importance, or whether adding to or deducting from the amount of work covered by the estimate, should be accurately put on record with just as much care as would be displayed by the lump-sum contractor. The original estimate should be modified accordingly and the owner's approval of the change secured, thus obviating any misunderstanding as to the estimated total outlay. Probably lack of attention to this matter has done more to create a prejudice against percentage work than any other factor, for only too often have owners been seriously misled as to the disbursement that will be required, because of failure to place properly on record the cost of changes or additions authorized during the construction period.

Practically all the reasons advanced in favor of the preparation of detail plans and specifications by engineering organizations, rather than by engineers that may be in the employ of an industrial company, apply in the case of the handling of construction work by construction organizations that do nothing else, as opposed to a force of men brought together for this purpose by an industrial company and directed by them. Unless the routine conduct of the industrial company's affairs includes as one of its functions the maintenance of a construction force organized specifically for such work, the only way that they can directly control the operation in a broad manner and at the same time expect an efficient result is to retain a thoroughly organized force of experts in accordance with the manner that has been outlined.

Chapter VI

PERIOD OF OCCUPATION AND COMMENCEMENT OF OPERATION

IT has been customary for industrial managers who are confronted with the necessity for providing new quarters for the conduct of their business to handle directly all matters incidental to the period of occupation and commencement of operations. This procedure was necessary so long as it was not possible to engage engineering firms experienced in the solution of the industrial problems covered by the Chapters II and III. When the owner, himself, had to determine the extent and character of the plant, it is obvious that the work incidental to the occupation of the buildings was also incumbent upon him. He can now, however, be relieved of this detail and in addition benefit through the experience of others, if competent industrial engineers are placed in charge of the entire undertaking.

M-a. Moving equipment and accessories from old plant into the new, transferring force, and starting up work.

Each commission presents special conditions which must be taken into account when moving from an old plant into a new one, or when rearranging departments and equipment in existing quarters with a view to occupying extensions that have been built. Usually this work can be done to best advantage in a very gradual manner, and yet it should be pushed forward decisively and in accordance with a carefully predetermined plan.

Reference has been made previously to the manner in which all the work incident to the building of a plant should be scheduled, and this applies also to the various provisions that must be made in connection with the occupation of the property. The building details should be laid out in the beginning not only to allow for the erection of line shafting, conveying apparatus, or other equipment that is attached to the structures, but wherever possible all auxiliary parts should be made and put in place or assembled to assure their correctness prior to the disturbance of conditions in the old plant.

Important details are almost sure to be overlooked unless a careful study is made in advance and some form of graphical routing diagram prepared. Every effort should be made to have installed all new machinery, including cranes, industrial railways, elevators, conveyors, and process equipment, well in advance of the moving period, for it is chiefly in regard to these that some difficulties may be encountered, owing to the lack of complete familiarity with correct methods of operation. The situation at this time is similar to the period given up to the preliminary service, in that a more speedy consummation of the entire work is attained through deferring the actual moving until every detail is attended to, just as the detail plans and specifications can be prepared in much less time if the manner of satisfying the requirements of the business are definitely fixed in advance. In each case it requires a thorough appreciation of this fact to avoid a procedure that may be expected to expedite completion, but in reality may cause complication and delay and therefore additional cost.

The nature of some businesses is such that it is imperative, if an entirely new plant is to be occupied, to suspend all productive work while moving; but more frequently the departments can be moved separately so that during the transition period the work will be divided between the old plant and the new. Of course, the proximity of the old and new properties has a great deal to do with the procedure and when the new quarters are on an adjoining site, being but an extension to the plant, the simplest condition prevails.

M-b. Correcting minor discrepancies that invariably evidence themselves after the plant as a whole is put into operation.

Minor errors in judgment or discrepancies in the working plans invariably crop up during the building of a large industrial plant, and these are of course, corrected by the engineers during the building period. It is on account of the familiarity these engineers have with structural details that they should in all cases superintend the actual construction work.

If the engineers perform the preliminary industrial work and make the equipment layouts, their co-operation is especially necessary as it is difficult for even experienced men to anticipate all the conditions that should govern the exact location of every machine, fixture, or piece of auxiliary apparatus, and the one who made the initial studies is likely to discern most quickly wherein they can be improved.

While the details to which reference has just been made may be comparatively unimportant when considered individually, in the aggregate they may have a very material bearing upon the efficiency of the plant.

M-c. Training the force of administrators and operators along the lines necessary to bring about the most efficient utilization of buildings and other facilities provided.

It is invariably the hope of those who build new industrial plants or large extensions to existing properties, that the work of manufacture will be conducted somewhat more efficiently under the new conditions than was previously possible, and as in some cases this is the principal motive that prompts the building work, it is evident that interest in the proposition as a whole must not be allowed to flag as construction nears completion, but should rather be stimulated as the time approaches when the merits of the layout can be measured.

A plant that has been in operation for a considerable period is almost certain to present a number of marked physical drawbacks, which cannot be corrected through methods of administration. Such matters will be corrected of necessity if the preliminary work is conducted in the manner previously described. However, the increase in efficiency should be much greater than is possible through the correction of these inherent disadvantages presented by the plant itself.

I refer to the results that should be secured through establishing conditions favorable to the most appropriate system of management for the plant, conditions which to some extent affect the layout of the plant as a whole and the character of the buildings, but which as a rule have to do more particularly with the internal arrangement of departments and equipment, the various enclosures required for shop offices, tool rooms, stores departments; the special bins, racks and other auxiliary appliances required in these departments; the provisions for checking employees in and out of the plant, etc. If the preliminary work has been properly performed, the buildings will have been so planned that all these detail arrangements can be made, but during the pressure of the early work it is often impossible for the engineers to inform the owner of the multiplicity of reasons that dictate certain recommendations, much less record them in such a manner that the owner and his people could carry them out successfully. I do not mean to imply that the engineers should not secure their principals' full approval of their work, but rather that the approval is secured without elaborating upon many of the factors with which we are dealing now, and which often do not influence greatly the character of the buildings proper.

An increasing number of industrial managers are constantly seeking the co-operation of men who specialize upon the broad subject of industrial management. These managers are necessarily men of initiative, who are willing to face problems of reorganization and the need of physical changes in arrangement of equipment, stores departments, and so on, owing to their implicit confidence in the wisdom of taking advantage of every advance in administrative methods that has a proved value. Even managers who may not be willing to admit that such a procedure as has been outlined will be wholly beneficial in their case under ordinary circumstances, agree that when occupying a new property there can be no doubt as to the desirability, and in many instances the imperative need, of placing the entire organization upon as economical and sound a basis as the present status of industrial affairs allows.

If the engineers who laid out the new plant are themselves, or have associated with them, men who are acknowledged authorities in the field of industrial organization, the owner should strive to profit to the fullest extent during the moving period by encouraging them to advance their opinions freely in regard to the manner in which the work should be conducted for which the plant was built. Of course, this service is a specialty in itself, and not necessarily a part of the work that must be performed when planning and building an industrial plant, other than to the extent of recognizing broad principles, as has been previously covered. The owner is fortunate who is able to devote attention immediately to the perfection of the system of administering his plant as soon as it is occupied, for then the greatest possibilities are presented.

CHAPTER VII

ROUTING; A PRIME FACTOR IN PLANT LAYOUT

THE primary purpose of this chapter is to call attention to the advantages that can be derived from the use of the graphical routing diagram as a basis for the planning of industrial plants. This diagram, as its name implies, indicates the paths or routes followed by the materials of manufacture when passing from their crude to their finished state, and in its final development it absolutely defines the plant in all particulars of layout.

Many industrial plants are seriously handicapped through the fact that the *arrangement* of their departments and equipment imposes operating expenses that are almost prohibitive. If errors are made in the selection of certain machines or other detail features, they can usually be corrected at comparatively small expense. On the other hand, if the arrangement of departments and equipment, and therefore the character of the buildings, has been incorrectly solved, the resulting plant may be such as practically to prohibit the establishment of correct conditions unless a very great monetary loss is incurred. It is becoming generally appreciated that this is a question deserving the utmost consideration, and as the efficiency of a given plant is governed primarily by the *manner* in which its layout is worked out, a method that has been found to be sound would appear to merit considerable attention.

The first step when preparing to lay out an industrial plant is, of course, to become thoroughly conversant with all the manufacturing requirements imposed by the particular business to be housed. This phase of the subject was discussed at considerable length in preceding chapters. When working up the layout, it is of primary importance that all these detail factors should be considered collectively so that their inter-relationships can be properly discerned. The graphical method allows of this more readily than any other.

Figure 1 is presented as an illustration of the routing diagram in its most elemental form.* It pertains to a series of conditions not particularly unlike those very frequently presented. In the upper left-hand corner is shown in plan a factory used exclusively for the manufacture of pianos. All the buildings, except the one marked with the letter "F," were in existence at the time the work was undertaken. The object in view was the establishment of conditions more favorable to economical manufacture of pianos than were afforded by the existing layout, which was the result of a growth extending over many years but not in accordance with any definite plan for the ultimate development. In addition, a very material increase in output was to be provided for. The product consisted of pianos of both grand and upright types, but for the purpose of simplicity the lines on the diagram have been drawn in for grand pianos only.

A grand piano is composed of a number of principal units, only seven of which we need consider. The essential parts of five of these, viz.; the top, rast, rast bracing, rim, and keyboard, are made of lumber and so start in their crude shape at the lumber pile. The plates are made of metal, and in this

* Fig. 1 is a folding insert facing page 112.

case the preliminary operations were performed in a shop not a part of the group of buildings in question. The sounding boards were also made at another shop. The location of the main lumber storage was originally as shown on the plan, but the disposition of the space in buildings D, C, B and E was quite different from that indicated. The first diagram prepared showed as accurately as was possible the manner in which the materials progressed through the plant at the time of the initial investigations, and a study of this diagram formed the basis for a series of revised layouts. These showed the paths of travel in two directions only, from floor to floor and in a direction parallel to the front property line, as it was necessary to establish broad relationships before taking up the routing in detail. The floor space required for the estimated increase in output was approximated and, as buildings D, C, B and E were satisfactory for general manufacturing purposes, it was found to be practicable to dispose of their floors in a manner best adapted to the routing of the product. The studies showed the desirability of extending the plant at the point indicated on the plan by building F. Finally, diagrams showing the various floors in plan were prepared, but insofar as is allowed by a diagram showing routing in elevation only, the final arrangement is shown by Figure 1. The sequence of the principal operations is indicated as well as the points where the various units are assembled.

While a diagram which is carried out in no greater detail than Figure 1 gives comparatively little information that is of specific value as a basis for the design of buildings and installation of equipment, yet it is a *key* to the manufacturing problems as a whole, and a useful and, in fact, a necessary step toward the final solution.

When decisions have been reached as to the areas of departments, their general arrangement, and whether or not they must be located on the ground floor, and when the necessary trucking and railroad facilities have been defined and a site tentatively chosen, a more advanced form of routing diagram can be prepared than was illustrated by Figure 1. If the building is of the single-story type, the routing can be satisfactorily shown in a manner indicated by Figure 6, but if the buildings are multiple-story this method requires the preparation of wholly separate diagrams for each floor and the advantages of graphical representations are not nearly so pronounced.

Figure 3* exemplifies the proper manner of recording graphically the routing of the product in multiple-story buildings. Of course, in actual practice the same result can be approximated through showing the floors in outline perspective as in Figure 4, leaving out the building detail. Diagrams of this character should be made prior to locating individual machines and, in fact, they become the guide for the performance of this work. The departments need to be considered individually only when locating machine equipment, and the routing diagrams showing the progress of materials from machine to machine represent the last step to which the work can be carried.

We will now consider the principal factors which brought about the diagram illustrated by Figure 3. In this case the plant indicated by the perspective comprises entirely new buildings to accommodate a business formerly conducted in another factory. The broad requirements for which the plant was laid out were a daily output of 150 dozen

* Fig 3 is a folding insert facing page 124.

rough stiff hats, 300 dozen finished stiff hats, 100 dozen rough soft hats, and 150 dozen finished soft hats, making 700 dozen or 8,400 hats per day. It should be explained that rough hats are made by certain manufacturers for customers who desire to perform the finishing operations themselves. These finishing operations comprise, for stiff hats, operations 29 to 42 and for soft hats, 21 to 31 inclusive (see Figure 3). It will not be necessary to consider all of the operations individually. The preparation of the chart required only such knowledge concerning the detail methods employed as was necessary to give a thorough understanding of the manner in which hats are made. The problem primarily was to plan a factory that would immediately provide for the output of hats specified above and also provide for reasonable growth of departments.

The preliminary routing studies revealed the fact that the work of the manufacturer comprises three clearly defined series of operations; first, those dealing with the skins from which the fur is obtained for making the hats, including the removal and preparation of the fur; second, the forming and shaping of the hat body up to a point where the

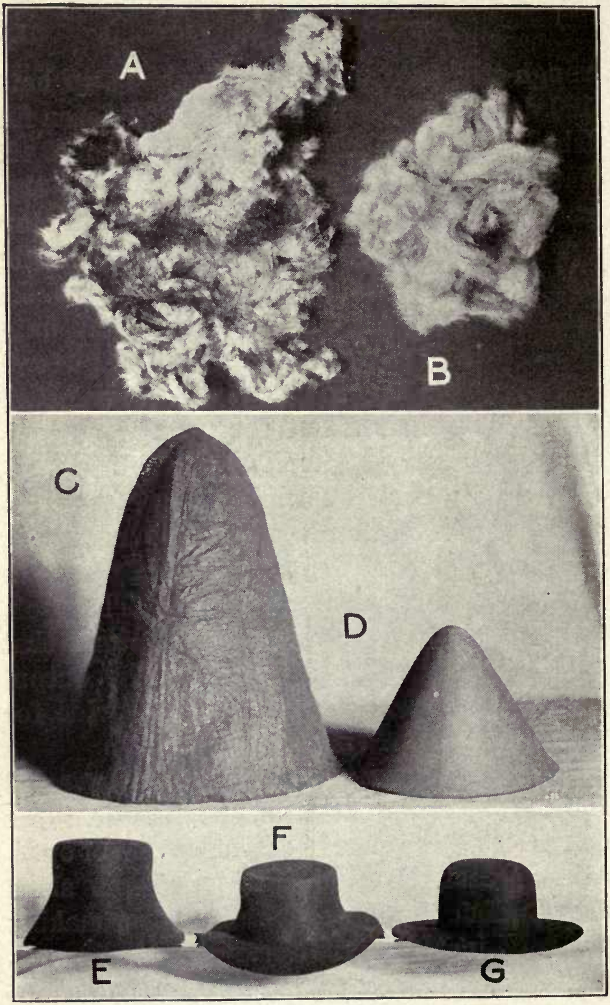

FIG. 2. STAGES IN THE MANUFACTURE OF STIFF HATS.

"rough" hat is produced; and third, the finishing operations that must be performed upon the rough hat body in order to bring about the final product.

The first series of operations comprises operations 1 to 4 inclusive for both soft and stiff hats. Operations 2, 3 and 4 represent in each case a series of distinct processes performed in part by labor but principally by special machinery. After the fur and hair have been cut from the skin, it is imperative that it should not come in contact with water. Further, the blowing which is done for the purpose of removing the hair from the fur is performed in machines made up of a series of compartments into which air is blown and, owing to the speed at which the fans operate, a reasonably substantial foundation is required. As the blowing equipment occupies a very considerable part of the total space required for the performance of the operations in question, the nature of the enclosure used to house them should be suited primarily to the requirements imposed by it. In this case it was decided to arrange the

Explanation of lettering on Fig. 2:—A, rabbit fur after operation No. 3; B, rabbit fur after blowing, operation No. 4; C, hat body after operation No. 6; D, hat body after operation No. 14; E, hat body after operation No. 23; F. hat body after peration No. 34; G, hat body after operation No. 28.

blowers in series of twelve sections, running parallel and across the building.

The second series of operations comprises numbers 5 to 28 inclusive, which are characterized by the fact that the principal processes in this group are effected through the alternate wetting and drying of the product from which the hats are made. Operation 6 forms the loose dry fur into the felt body which is the first definite form assumed by the product when making stiff or soft hats (Figure 2). This is accomplished by feeding the fur, which has been previously weighed, into the top of a cylindrical shell about 4 feet in diameter and 5 feet high, at the bottom of which is a rotating table that carries a finely perforated copper cone about 24 inches in height. The fur entering the cylinder in a finely divided state is deposited against this copper cone by means of the suction created by an exhaust fan, which draws the air through the perforations and down through an opening in the spindle of the rotating table. The rotary motion is only for the purpose of assuring the deposit of a uniform layer of fur upon the cone. When the requisite amount of fur has been so deposited, the cylindrical shell is opened, wet cloths are wrapped around the cylinder to hold the fur in place, and it is then lowered into a tank of hot water. This dipping starts up the felting action which is the basic principle upon which the manufacture of hats of this kind depends. Each individual fibre of the fur shows, under microscopic examination, numerous small barbs. The individual fibres are worked together by the interlocking of these barbs during the immersions in hot water and the subsequent hardening and sizing processes, which merely consist in *working* or *kneading* the hat bodies upon a bench or in machines.

This group of operations contains the stiffening processes, numbers 15, 16, 17 and 18, which in reality form a distinct sub-group by themselves. The presence of large quantities of alcohol introduces a considerable fire hazard and, in addition, the equipment required for this work necessitates special building features. Except for these stiffening operations, it will be seen that the processes of the second group merely subject the felt body to a series of gradual changes in shape in a manner that necessitates repeated water immersions. Therefore, the work is characterized by the fact that large amounts of very hot water are used, requiring special provision for drainage and ventilation and calling for complete segregation from the first and third series of operations, in connection with which the complete absence of water is a necessity. Another feature pertaining to this part of the work is that all the product passing through the processes just referred to is upon stock orders rather than upon customers' orders and, while this condition might not prevail in another hat factory, it was an established practice in this instance.

Operations 29 to 44 for the stiff hats and 21 to 33 for the soft hats are all performed through the medium of dry heat—at least, those that have to do with changing the form of the crown or brim. Further, whereas the hats are made for stock orders during the second series of operations and can be stacked in piles one over the other, so requiring very little room for storage between operations, during the third series they are made for customers' orders and must be handled in much smaller lots; and as the crowns have been formed they must be stored individually in special racks provided for the purpose. Consequently, when in transit they occupy a large amount of floor space as compared with that needed prior to the formation of the rough hat body.

Several diagrams were prepared before the final one illustrated by Figure 3 was produced. It will be seen that a separate building is provided for the first series of operations, including also the first operation of the second series, viz., the forming and hardening of the hat body. Operation 6 is housed in the same building as operations 1 to 5, because the fur should be carried the least distance possible between blowing and forming, and also because a structure suitable for the installation of blowing machines is adapted also for the comparatively heavy forming equipment. Further, these two types of equipment require the major portion of the power needed for the entire plant; so, as the direct drive had been decided upon, it was considered advisable to locate them in as close proximity as possible and near the engine room. There are no industrial objections to the use of a multiple-story building for these operations; in fact, a study of the diagram will show that such a structure has certain advantages; consequently a three-story building was adopted.

The requirements of the operations comprising the second group, exclusive of the stiffening processes, were such as to make a single-story building with adequate roof ventilation and floor drainage preferable. The locations of the various departments were worked out with a view to minimizing the travel of the hat bodies and at the same time making possible the use of but one dry room serving both stiff and soft hats. It will be seen that the dry room is located in the center of the building, and although all the soft hats and stiff hats must go into this department four times before they pass to the third and last series of operations, this is accomplished with a minimum of handling. There are six means of entrance or exit to the dry room, allowing practically a continuous movement of material in well-defined directions and obviating the possibility of congestion.

The stiffening operations are housed in a separate fireproof enclosure designed especially for this purpose, and separated from the rest of the plant in order to confine the area subjected to extraordinary fire risk.

It has been pointed out before that a very considerable amount of space is occupied in connection with the third series of operations for hats in transit, and on this account the total floor area is much greater than is required for the preceding group. Further, there is a great deal of the work that is performed upon benches which requires a very good light. Therefore, it was decided to adopt a three-story building, in order to combine the necessary floor space and bench room along windows and at the same time a desirable routing of the materials. It will be seen that considerably more space is required for finishing the stiff hats than for the soft hats. In order to keep the two kinds of work segregated, the first and second floors are utilized for the former and the third floor for the latter. These finishing operations, which are performed in the building to the extreme right of the diagram, constitute a complete business in themselves. The rough hats are stored in the first floor directly in the foreground of the perspective, and are shipped from the finished-stores department located at the far end of the same floor and directly adjoining the railroad siding.

While it was not practicable to include in diagram No. 3 a very great amount of detail, yet it should be pointed out that it is through the medium of such a diagram that the overall dimensions were fixed and building characteristics determined. It will be clear, after it has been studied in detail, that every square foot of floor space is provided for a specific purpose, so that the expenditures for the plant were confined strictly to those needed for the output immediately desired. In order to comply with this requirement, the building provided for the second series of operations was designed to the dimensions indicated rather than a single rectangle in outline. It will also be noted that the second and third floors of the finished building have been set back so as to provide just the areas needed. However, the plant can be extended readily to provide for growth, without necessitating a rearrangement of departments, except for the equipment used in connection with operations 10, 11 and 12. This would have to be moved into an extension of the building in order to allow for the growth of the dry room. In general the buildings for the first and third series of operations would be extended into the foreground of the illustration, and the building for the second series of operations would be extended at either or both ends, depending upon whether the increase was in stiff or soft hats, or both. The only limiting factors in the extension of the plant as a whole are those imposed by the location of the stiffening building and the size of the property. The hat industry is a particuarly good one to refer to as a means of illustrating the advantages of the graphical routing diagram, as the process work consists in a large measure of the performance of work upon but a single article, causing its gradual change from the first felt cone to the finished hat. In the majority of industries work must be performed upon a great number of small parts which, of course, makes the routing problem a very much more complex one. Under such circumstances there is almost sure to be a considerable amount of travel in a backward direction, and the arrangement of departments and equipment that is finally adopted will represent, at the best, but a compromise of many conflicting conditions. In contrast with this state of affairs, it will be noted that the routing lines shown in Figure 3 progress uniformly from the point where the work commences to the shipping department, and indicate to all intents and purposes the actual paths over which the

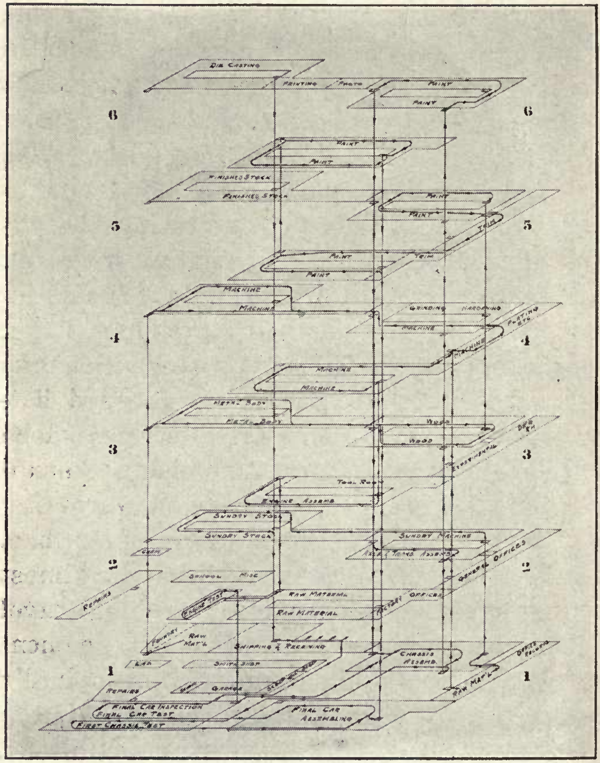

FIG. 4. PERSPECTIVE ROUTING DIAGRAM, IN OUTLINE, SHOWING PATHS FOLLOWED DURING MANUFACTURE OF PRINCIPAL UNITS ENTERING INTO GASOLINE AUTOMOBILES. SEE PAGE 127.

specially designed trucks used for transporting the hats are moved.

In actual practice it is not feasible to work up a number of alternate diagrams in as great detail as the one that has just been described, but a very satisfactory result can be secured by laying out the various floors of multiple-story buildings in outline perspective, indicating the routing lines in the manner shown in Figure 4. This diagram, like the one illustrating the progress of the materials through the hat factory, shows the plant as a whole but does not give in detail the actual routing that would take place within individual departments. Nor has any attempt been made to route the individual parts, numbering several thousand, that enter into the construction of a complete gasoline automobile. The diagram is in reality but a "key," indicating the principal paths of travel of materials from the point where they are received until they reach the shipping department in their completely assembled state. The detail routing for such a plant must be shown on large-scale drawings of individual departments. Figure 5 is a perspective view showing the exterior of the plant as a whole.

A diagram illustrating the fullest application of the routing principle is illustrated by Figure 6, which shows the layout of a plant

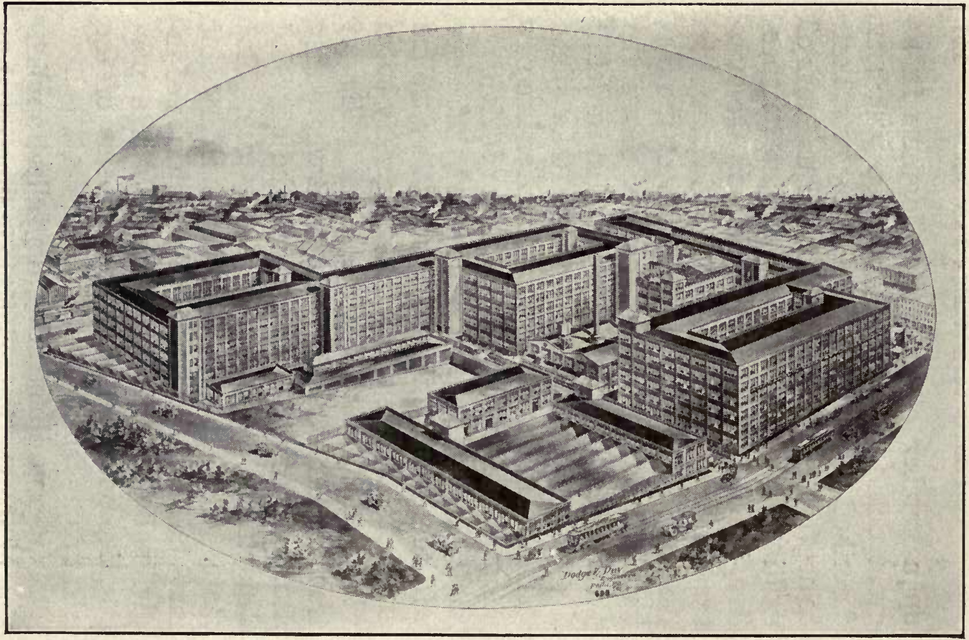

FIG. 5. EXTERIOR VIEW OF AUTOMOBILE PLANT TO WHICH THE ROUTING DIAGRAM (FIG. 4) RELATES.

used for the manufacture of wagon and carriage axles. In this instance the location of each piece of equipment is clearly indicated on the blue print and the routing lines show the exact paths followed by materials from the point where they are received until finished and ready for assembling with wheel boxes. This illustration was chosen as it represents a plant complete in every particular.

A consideration of the series of diagrams which accompany this article will serve, I am sure, to emphasize the fundamental importance of the routing problem as bearing upon the laying out of industrial plants. In order to develop the routing scheme properly one must make a thorough study of all the more important factors entering into the business that is to be housed, and on this account the routing diagram forms the logical basis upon which to develop and reconcile all detail considerations, for it is in this particular that they all have a common ground. The problem is in its essence one of determining the inter-relationships which should exist among an aggregation of acts and operations in order to accomplish a given result with maximum economy. Now, in order to determine whether a given series of acts or operations is a desirable one, it is imperative to consider the effects produced by each upon those that follow, for the conditions existing at every stage are the result of all prior acts or operations. Therefore, the pri-

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Explanation of lettering on Fig. 6:—

1, 4-in. bar shear. 2, oil furnace. 3, forging press. 4, 100-lb. hammer. 5, clipping shear (old 3-in. bar shear). 6, oil furnace. 7, 2½-in. Ajax taper rolls. 8, 2½-in. upsetting machine. 9, oil furnace. 10, 400-lb. Yeakley pneumatic hammer. 11, oil furnace. 12, 4-in. taper rolls. 13, 4-in. upsetting machine. 14, punch press. 15, 24-in. by 72-in. oil furnace. 16, 600-lb. Yeakley pneumatic hammer. 17, No. 6 Williams White bulldozer. 18, oil furnace. 19, Queen City pressure blower and oil pump. 21, portable hydraulic axle-straightener (50 ton). 22, 18-in. by 18-in. oil furnace. 23, 1¼-in. triple axle ram. 24, 16-in. by 6-ft. Porter lathe. 25, 20-in. by 10 ft. Garvin lathe. 26, 1¾-in. single axle ram. 27, 3-in. single axle ram. 28, double-head axle lathe (Bridgeford). 29, 42-in. by 14-ft. engine lathe (30-in. lathe raised). 30, 20-in. by 8 ft. engine lathe (for filing work). 31, 22-in. by 12-ft. engine lathe (for filing work). 32, Whitney milling machine (for cutting oil grooves). 33, 1½-in. single-head Acme bolt-cutter. 34, 2½-in. ditto. 35, 20-in. by 8-ft. Johnson lathe. 36, 32-in. by 14-ft. Bishop lathe. 37, hydraulic press for forcing on loose collars. 38, double-head Acme 2-in. nut tapper. 39, nut-facing machine. 40, Monitor turret lathe for recessing nuts. 41, chucking lathe for loose collars. 42, 20-in. engine lathe (for finishing boxes). 43, ditto. 44, 1¼-in. quadruple box reamer. 45, 4-spindle drill (for reaming boxes over 1¼ in.). 46, 2-wheel grinder. 47, 36-in. by 18-in. case-hardening furnace. 48, tempering trough. 50, 14-in. by 6-ft. tool-room lathe. 51, 22-in. Sargeant drill press. 52, 20-in. by 20-in. by 5-ft. New Haven planer. 53, No. 2 universal milling machine. 54, 12-in. by 12-in. tool-tempering oil furnace. 55, Sellers No. 2 universal tool grinder. 56, surface grinder.

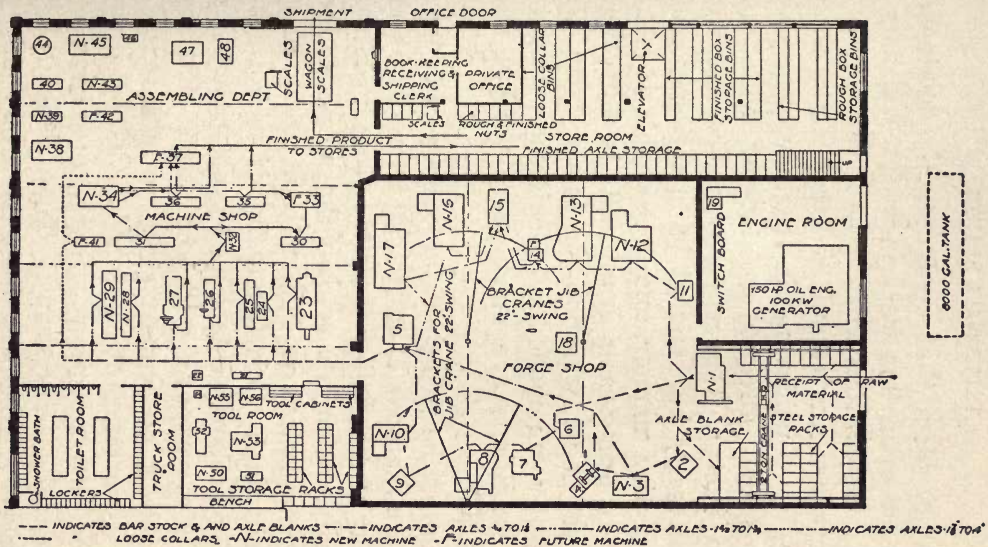


FIG. 6. DETAIL ROUTING DIAGRAM: MACHINE-TOOL EQUIPMENT AND PATHS OF PARTS IN A WAGON- AND CARRIAGE-AXLE PLANT. (See note, page 130.)

mary problem that confronts the engineer engaged upon this work is to forecast accurately results that will follow if certain procedures are carried out, and this can be done only by considering in regular sequence causes and effects, commencing with the initial factor. Consequently, the work must of necessity be handled in an orderly and consecutive manner, and if the habit of mentally grouping facts graphically is cultivated to the point where such images can be promptly summoned into existence, resulting conditions are much more readily anticipated.

One of the principal factors entering into modern methods of industrial administration is that of scheduling the work from a central planning office in a manner that provides for the completion of each unit of work in a certain time. It is found that if such a system is properly established great economies result as compared with any results that are possible if no regular schedule is enforced. The importance of the schedule is best illustrated in connection with the operation of large railroad systems. They depend for their very existence upon the exact adherence to a train schedule which defines the arrival and departure of every train at every important point upon the system. Such a schedule, however, can be carried out only after the tracks, terminals, yards, and stations have been laid out strictly in accordance with the requirements of the schedule itself. In other words, a routing diagram must be made of the entire system, based upon the series of schedules that it is proposed to establish. If a certain degree of flexibility can be provided for, this of course must be taken advantage of; but in any case there will be certain well defined conditions such, for example, as the location of sidings, distributing yards, etc., if it is a single-track line. This is a well-recognized principle in railroading and is fundamental to the operation of practically all systems, both large and small. The only reason that it has not been recognized as of almost equal importance in industrial work, is because an industrial plant *can* operate without any clearly defined schedule, and therefore without any carefully pre-arranged layout or routing plan. It is not a matter of the physical safety of those who own a plant or are employed as operators, although it may well be one of life or death insofar as the well-being of the business as a whole is concerned. Industrial managers now realize, as they never have before, that the scheduling of their work is one of the prime factors of economic production, and that operating expenses can be minimized only when the plant has been physically arranged in accordance with the requirements of the most efficient schedule.

Chapter VIII

METAL-WORKING PLANTS AND THEIR SPECIAL CHARACTERISTICS

IN the preceding chapters the manner in which the work of planning and building industrial plants should be carried out has been analyzed, formulated, and discussed. Consideration has been given primarily to certain broad principles governing this work irrespective of the output for which the plant is designed. Knowledge of these principles is effective only when it is coupled with a thorough understanding of the special requirement of the particular business we are providing for. The next logical step in the development of this subject is, therefore, the study of the characteristics of the particular type of plant most interesting to the large majority of those concerned with the engineering industries. This is the plant whose predominant function is the working of metals.

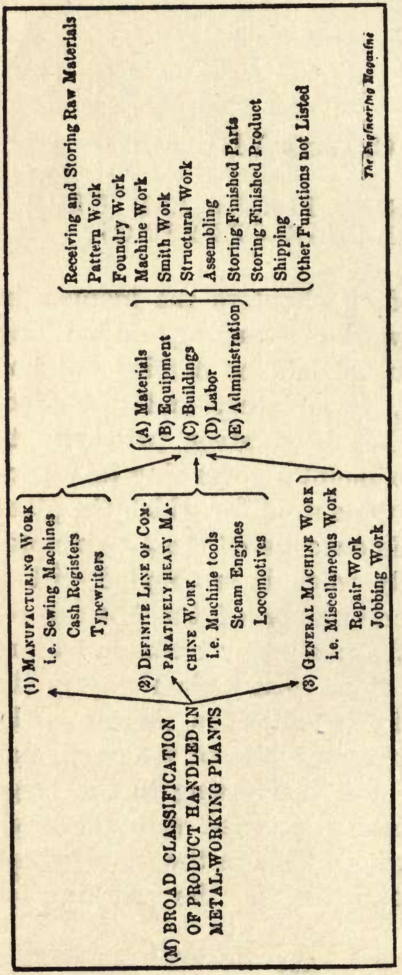


FIG. 7. CLASSIFICATION OF METAL-WORKING PLANTS.

Even here specific requirements vary widely in different branches of the metal trade. Conditions are not exactly the same in any two cases. Nevertheless, metal-working plants have well-defined characteristics which can be classified according to the specific aims of the particular establishments included in the general category. I do not propose now to include in this group smelting or reduction of crude materials to metallic form, nor the making of castings; but only those manufacturing establishments and (more particularly) the machining departments, in which metals are converted into ultimate commercial products such as machine tools, automobiles, generators, watches, etc.

The various kinds of plants under consideration will be divided into three groups, depending upon the character of their output (Figure 7, opposite). The nature of most metal-working businesses is such that they do not fall wholly within the clear confines of any one of the groups, although in almost every case there is a predominating tendency toward one of them. It will be shown that the exactness of solution that can be attained when laying out a new plant differs in degree quite markedly for each of the groups, being a maximum in the first and a minimum in the third. A proper understanding of this condition results in a much clearer conception of the whole subject.

The conduct of all business coming under the classification in question involves five factors, *i. e.,* Materials, Equipment, Buildings, Labor, and Administration. Each of the departments or kinds of work indicated to the extreme right of the chart comprises all of these factors, the names being merely indicative of the functions performed. This self-evident fact is alluded to only because it is the purpose to show that while machine work, smith work, the storing of parts, etc., are common to all of the plants coming within the classification, yet the manner of providing for and administering each of these has well-defined characteristics which can be logically sub-divided for the purpose of analysis in accordance with the three groups given in the chart. These characteristics are briefly referred to below and can be identified by the letters and numbers.

I wish to emphasize that this analysis is for the purpose only of setting forth some of the more important requirements of metal-working plants in a manner that may possibly prove helpful to the engineer engaged upon this work, through giving him a more comprehensive understanding of the limits attainable in the satisfaction of the conditions imposed by the principal branches of the metal-working industry.

M—(1) MANUFACTURING WORK
(Characteristics)

M (1) a—Materials—Usually of such a character and required in such quantities that they can be readily handled and stored through the provision of special tote boxes, racks, bins, etc.

M (1) b—Equipment—Principally special in character; sometimes available as stock machinery, otherwise built to order in accordance with special designs.

M (1) c—Buildings—Single-story or more often multiple-story—of types standard for such structures considered on their own account, the product not being an influencing factor.

M (1) d—Labor—Comparatively low-grade help skilled in the performance of single operations, excepting a small part of the force composed of high-class mechanics.

M (1) e—Administration—Clearly defined conditions as to materials, equipment, and functions of employees permits of the most ready establishment of a fixed policy as to operating methods and provisions for expansion.

M (1) a, b, c, d, e—The problem of plant layout for industries in this group permits more readily of exact solution than for either of the groups that follow. Equipment is largely special. Buildings are of standard types suited to property conditions. Administration methods are capable of accurate definition, and standards can be adhered to owing to the repetitive feature of the manufacture. The final layout of equipment and buildings indicates directly (to a very considerable extent) the desired method of operation.

M—(2) HEAVY MACHINE WORK
(Characteristics)

M (2) a — MATERIALS — Usually comparatively heavy, quite diversified and bulky, so making the solution of handling and storing methods more difficult than for shops in the first class, although reasonably fixed conditions are presented.

M (2) b—EQUIPMENT—Generally stock machine tools, adapted to a considerable range of work as compared with the wholly special equipment characteristic of the first class.

M (2) c—BUILDINGS—Special to suit the size of the work performed in them, and incorporating structural features that are used in the same sense as equipment.

M (2) d—LABOR—A predominating part properly experienced in respective trades, not merely skilled in the attendance of machines performing single operations.

M (2) e—ADMINISTRATION—Conditions as to materials and equipment and functions of employees are not capable of standardization in the sense that is practicable in shops of the first class, so that intelligent direction of the work requires the constant application of scientific methods based upon elemental understanding of all factors involved and applied through carefully devised system.

M (2) a, b, c, d, e—The problem of plant layout for industries in this group is the most complex;

for, while capable of reasonably definite solution, the greatest variety of factors is presented. Equipment is largely comprised of standard types of machines. Buildings are special. Administration is complex. The final layout of equipment and buildings suggests directly only in small measure the method of operation intended.

M—(3) GENERAL MACHINE WORK (Characteristics)

M (3) a—MATERIALS—The character and amount of materials can be anticipated only in small part, owing to uncertainty of kind of work that will be done. Consequently, there is imposed a wide demand upon the receiving and stores departments.

M (3) b—EQUIPMENT—Principally stock machines suited to very wide range of work. Occasionally special machinery for possible repairs on special parts. Selection of types and determination of amount of equipment can be approximated only.

M (3) c—BUILDINGS—The character of work to be done is usually a governing factor in their design. Precise definition of types and sizes is, however, seldom practicable.

M (3) d—LABOR—Especially versatile in respective trades. Possibly not so capable at any one job as operators in shops of second class, but competent throughout a much wider range of performance.

M (3) e—ADMINISTRATION—The system of management must be the one that will prove most effective under circumstances that make it impossible to anticipate exact conditions from day to day. Each case must be worked out along special lines and often conditions are such as not to justify a highly perfected system.

M (3) a, b, c, d, e—The problem of laying out plants coming within this group is capable of the least definite solution. Equipment is largely standard, suited to wide range of work. Buildings standard or special, depending on the kind of work that is desired. Administration methods must be suited to the uncertain conditions and, while in one sense the conditions call for the most highly perfected system, incidental conditions prohibit or do not justify their introduction. In any case, it is system that works from day to day and cannot plan for the future.

The purpose of classifying our subject in the manner given above was, primarily, to provide a logical basis for its discussion. We will now consider, individually, each of the factors composing the three principal groups.

M (1) a—Materials—Usually of such a character and required in such quantities that they can be readily handled and stored through the provision of special tote boxes, racks, bins, etc.

The term "Manufacturing Work" is used in the customary industrial sense—namely, the kind of work that involves the making of certain articles in very large quantities, the repetition of various operations being the essence of the manufacturing feature. The necessity of manufacturing in such large lots as we have under consideration arises principally in connection with articles that are purchased for individual use, such as watches, cooking utensils, typewriters, sewing machines, etc. Of course, there are exceptions to this rule, such as the automobile, but even in its case the actual manufacturing operations are performed upon comparatively small parts.

Consequently, materials purchased by manufacturing concerns are characterized by their comparative lightness and the fact that they are required in great quantities. Therefore, the stores department can be laid out with very considerable accuracy, providing special bins and racks for the storage of different material and they can be efficiently transported in lots through the use of tote boxes or other equipment adapted particularly to them.

M (1) b—Equipment—Principally special in character, sometimes available as stock machinery, otherwise built to order in accordance with special designs.

The types of special equipment used in manufacturing plants are designed ordinarily for the performance of but a single job, or in many cases, but for a single operation. Frequently, however, adjustments are provided which permit of the performance of other jobs or operations which are of the same general kind, but usually special equipment is used exclusively for the performance of certain fixed operations. There is special machinery for which there is so large a demand that it is a regular line of output of certain of the machine-tool builders; and then again, the machinery used to manufacture special articles which, either through patent protections or for other causes are made only by one or at the most a few concerns, must be built to order in accordance with special designs. The ability exercised in the design of such equipment has, necessarily, a very great bearing upon the efficiency of the plant, as the amount of output is directly dependent upon the performance of the machines themselves.

It is particularly in regard to equipment designed for the manufacture of articles for which there is a large demand that standard types have been perfected, the use of which can be counted upon when laying out a new plant. It is not practicable as a general thing for the engineer who is engaged upon such work to take under consideration the design of process apparatus or special machinery. Therefore, he is confronted with a very specific problem in so far as equipment is concerned.

M (1) c—BUILDINGS—Single-story or more often multiple-story—of types standard for such structures considered on their own account, the product not being an influencing factor.

Several functions are performed by the buildings used to house industrial work, the more important of which are; first, to afford protection against unfavorable weather; second, to allow of a floor area greater in the aggregate than the area of the property occupied (accomplished through the adoption of multiple-story structures); third, to afford fire protection; and fourth, to serve in part as equipment through providing the means of support for line-shafting, traveling-crane runways, etc. The first three considerations usually govern for the class of work that we are considering. As manufacturing work is light in character, the amount of head room between floor and ceiling that is required for proper light and ventilation (which is satisfactory for light overhead line shafts), is found to be adequate. Therefore, the building structures are not governed specifically by the detail processes of manufacture, but are types suitable for various other classes of occupancy. It is often desirable, from the standpoint of investment, to assure the fulfilment of this condition even if slight industrial disadvantages result.

The sketches on page *** and *** show buildings of multiple-story type suited to general manufacturing operations. The illustrations on following pages exemplify buildings belonging to the second and third groups in the classification here adopted—that is, to definite, comparatively heavy machine work or to general machine work.

M (1) d—LABOR—Comparatively low-grade help skilled in the performance of single operations, excepting a small part of the force composed of high-class mechanics.

When the character of the work is such as to lend itself to manufacture by means of special and automatic machinery, highly skilled operators are usually needed only for the performance of certain auxiliary functions—that is, the special machinery may require attendants whose entire duty it is to furnish the work to the machine and to remove the finished product. While this may necessitate a considerable amount of dexterity upon the part of such operators, the work is of such a nature that comparatively low-grade help can be trained to a high point of efficiency. The great advantage these manufacturing methods afford is that quality and quantity of work done are almost wholly beyond the control of the machine attendants. As a rule the class of operators just referred to are more readily disciplined than skilled artisans. The question of their segregation arises only when it is necessary to meet objections that may be advanced by skilled workers.

The maintenance of conditions that permit the employment of low-grade men is made possible, however, only through the fact that a small force of very high-class mechanics is engaged to make all of the dies, jigs, templets and other special accessories, and conditions favorable to their most efficient performance must be established. It is often desirable to segregate these men, and when their work has to do with the product in only an indirect manner, their services are made available to a number of departments turning out products which in themselves are quite different.

M(1) e—Administration—Clearly defined conditions as to materials, equipment and functions of employees permit of the most ready establishment of a fixed policy as to operating methods and provisions for expansion.

The purpose of a system of administration is to provide the executive with means for securing the results for which the plant is operated; viz., the manufacture of a certain output complying with fixed standards as to quality and made in certain definite quantities.

The administration of manufacturing plants is facilitated through the fact that the quality of the product is governed largely by the performance of machines, not operators, and that a fixed output can be secured for a given equipment. Fixed output under uniform conditions of attendance should result in uniform operating costs; the costs being low because the volume of work justifies special equipment, and uniform on account of the regularity of the output.

Owing to the fact that in the main standard types of buildings are suited to manufacturing work, it is usually a comparatively simple matter to provide for extensions through the construction of additional units of the same character, although when new buildings are occupied there is usually required a reapportionment of space in the original plant.

Owing to the special character of the equipment, there is no doubt as to the work which must be performed upon it, and even though there are a great number of parts entering into the product, the question of routing is a comparatively simple one, and the routing plan that is adopted is to a considerable extent made apparent by the layout itself. This is illustrated in a very simple form by a hat factory, where, if the trucks transporting the hats are removed in the manner made directly evident by the arrangement of the machinery in departments, they will practically mark out on the floor of the various buildings lines identical with those shown on the routing diagram (shown in a preceding chapter) and this would be true if those who operated the plant had never seen the diagram in question.

M (1) A, B, C, D, E—RÉSUMÉ

Owing to the precision with which most of the fundamental requirements of manufacturing plants can be defined, it is clear that they can be laid out with a very great degree of accuracy. The performance of special equipment is absolutely definite in character. The amount of such equipment required can be calculated with precision, and the amount of enclosed floor space needed can be readily ascertained after layouts of equipment have been made. Except for the buildings themselves, the entire plant is special in character and, in fact, this is true to such an extent as to make the layout as a whole useful in connection with the manufacture of but a single line of output. The number of plants that can be classed properly in the group we are considering is rapidly increasing owing to the tendency toward specialization which has become so marked a factor within recent years.

There are so many kinds of special equipment, that it will not be practicable to include actual illustrations,* particularly as many of them are familiar to the reader. The influence of the character of the work upon the types of buildings is, however, so very marked and interesting that a number of illustrations are given showing cross-sections

* Machine-shop equipment was discussed by Mr. Day in considerable detail in two articles that appeared in THE ENGINEERING MAGAZINE for July and August, 1909.

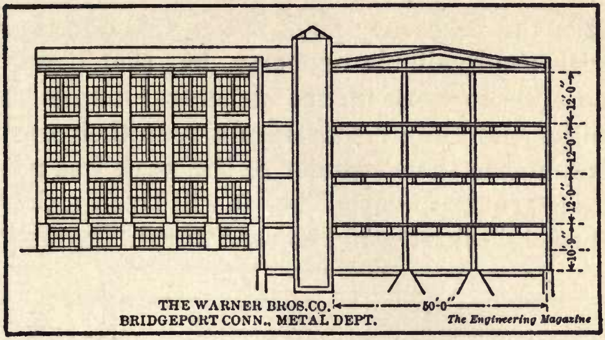


FIG. 8. TYPICAL BUILDINGS SUITED TO THE REQUIREMENTS OF THE FIRST, OR "GENERAL MANUFACTURING," GROUP IN THE CLASSIFICATION ON PAGE 136.

of certain existing shops that have been designed for particular lines of metal work. The small metal parts for the corsets manufactured by The Warner Brothers Company of Bridgeport, Conn., in the buildings shown in cross-section on page ***, are turned out in sufficient quantities to secure the full benefit of manufacturing methods. This condition is also well exemplified in the building (shown in cross-section on page ***) in which have been housed certain of the principal departments of S. L. Allen & Company of Philadelphia, manufacturers of light agricultural implements. It is clear that the structures in question, which are of the multiple-story type, were designed primarily to provide the necessary floor areas in connection with the available property, but that it was possible to work up the structural details to satisfy building requirements upon their own account as the character of the work was not a governing factor. Thus it will be seen that these buildings could be used advantageously

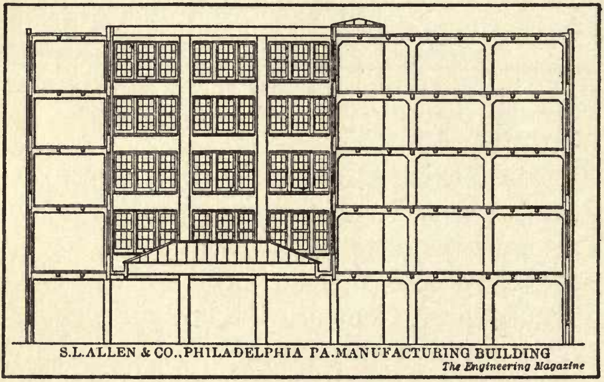


FIG. 9. TYPICAL BUILDINGS SUITED TO THE REQUIREMENTS OF THE FIRST, OR "GENERAL MANUFACTURING," GROUP IN THE CLASSIFICATION ON PAGE 136.

for other purposes than those directly intended, providing the floor areas were sufficient.

Having covered the principal requirements imposed by metal-working businesses that can be conducted upon a manufacturing basis, we will proceed to consider in the same manner the second class of shops, viz.: those that build given lines of reasonably heavy machinery.

M (2) a — MATERIALS — Usually comparatively heavy, quite diversified and bulky, so making the solution of handling and storing methods more difficult than for shops in the first class, although reasonably fixed conditions are presented.

The stores departments of certain concerns whose output would rightly fall in this class can be laid out with very great precision, because of the accuracy of their knowledge concerning the quantities of materials that should be available. There are other cases where no attempt is made to carry a considerable supply of finished product. The raw materials with which we are now more particularly concerned tend toward large and bulky parts, requiring for their handling and transportation special provision in the form of equipment, and often building features. It was pointed out that for plants coming within the first group the materials entering into the manufacture usually do not influence in any way the buildings proper. In this case, however, we find that the nature of the materials may necessitate floors designed for extraordinary loads, larger door and elevator openings than would ordinarily be required, owing to the nature of the materials, etc.

M (2) b—EQUIPMENT—Generally stock machine tools, adapted to a considerable range of work as compared with the wholly special equipment characteristic of the first class.

The class of work now in question is not sufficiently repetitive to justify the expense of special equipment, so the machine tools that are usually needed are the familiar types of engine lathes, boring mills, planers, drill presses, etc. They are designed particularly with a view to handling a diversified line of work, although the tendency within recent years has been more and more to narrow down their range. Each type is suited to the performance of certain operations, which may be required in connection with the machining of a great multiplicity of different parts entering into products used for widely diversified purposes. Therefore, this group of metal-working plants affords the engineer considerable opportunity for the performance of valuable service in connection with the selection of machine tools. This is the case because the problem is one of *selecting* the standard machines best suited to the performance of the various kinds of work, considered individually and collectively, rather than the task of designing special machines or auxiliary equipment for special operations which is presented by shops of the first class. The engineer who has had the necessary experience can perform the first function quite promptly, whereas the designing of special apparatus, even when the work is performed by experts, almost always requires an amount of time that is not available when planning a new shop.

M (2) c—BUILDINGS—Special to suit the size of the work performed in them and incorporating structural features that are used in the same sense as equipment.

The buildings for plants coming within the class in question must, as a rule, be designed with a view to meeting the special requirements imposed by the product. Overhead traveling cranes are often necessary, and insofar as the building structures are used to support the crane runways, etc., they contribute directly to the equipment of the plant. High head room is usually required under traveling cranes in order to allow of the erection of large machinery, and the heavy floor loads imposed, even in the machine departments, often necessitate special provision.

M (3) d—LABOR—A predominating part properly experienced in respective trades, not merely skilled in the attendance of machines performing single operations.

As stock machine tools adapted to a considerable range of work are used in plants doing the kind of work that we have under consideration, it is necessary to employ comparatively highly skilled operators. The fewer the parts that are handled, and in general the greater their bulk and weight, the higher must be the grade of the operators—assuming, of course, that a considerable amount of machine or other kind of work must be done upon the parts. Therefore, in shops where large steam engines are made we find that the average competency of the various workers ranks much higher than is the case in a plant making typewriters, although the intricacy of the latter product is much greater than that of the former. While this question of the character of the labor may not materially affect the physical features of the plant, yet it is one that must be thoroughly appreciated in planning a new property or an extension to an existing property.

M (2) e—Administration—Conditions as to materials and equipment and functions of employees are not capable of standardization in the sense that is practicable in shops of the first class, so that intelligent direction of the work requires the constant application of scientific methods based upon elemental understanding of all factors involved and applied through carefully devised system.

When complex conditions are encountered in connection with the planning of an industrial plant, it is certain that equally complex problems will arise in connection with the administration of the work to be performed when the plant is finished.

Owing to the fact that the greater part of the equipment is suited to the performance of a considerable range of work, and also because the number of parts of a given kind may be comparatively limited, it is frequently necessary to perform certain operations on quite a number of different pieces upon the same machines. For example, there may be forty or fifty parts entering into a complete engine lathe that require turning operations. Possibly at least 50 per cent. of these parts should be turned upon engine lathes of the same size and type, yet a very small number of these lathes would be sufficient for the entire diversified output. Here we find a state of affairs quite different from that presented by the first class of shops, where a majority of the machines are operated continually upon identically the same work.

As machines are not automatic, there are usually a number of different methods by which given operations can be performed, but only one of these represents maximum economy. Different kinds of work present variations in materials, diameters, and amount of material to be removed, so that speeds and feeds must be adjusted to the particular requirements; and as continuous operation is seldom possible, it is necessary to make these adjustments very frequently. In fact, changes in speeds and feeds and changes of cutting tools are often necessary for the performance of a single job. Consequently, the efficiency with which machines operate depends upon the degree to which conditions representing maximum economy are maintained.

The various operations upon different parts of the product do not necessarily have to be performed in a given sequence, although one sequence represents maximum economy. From the standpoint of the arrangement of the equipment to accord with the most desirable plan of routing, it is clear that it becomes imperative to establish the sequence in which the more important operations should be performed. Usually there are conditions, arising either from the character of the equipment that is available or the work to be done, making one schedule of operations more desirable than all others.

In view of the foregoing, it follows that the amount and arrangement of equipment must be based upon the assumption that a certain definite system of operation is to be enforced. It is not sufficient for the engineer to decide merely that the operations shall be performed in a certain sequence and the machines always adjusted for conditions representing maximum output, for he may be basing his layout upon a system of shop management that the personnel will be wholly incapable of enforcing. The question of shop management is so extremely subtle and comprehensive that it is not usually practicable for the engineer to attempt to bring about radical changes in the methods employed by those for whom he is designing a new plant, unless the requisite time is available and the engineer's principals have a thorough realization of just what the work is likely to involve.

There are, of course, certain details that are affected directly by the system of shop management that is adopted—for example, the character and location of shop offices, entrances and exits for employees, etc. In addition to providing for such matters, the engineer should aim to lay out the plant so that it will lend itself efficiently to the system of administration he approves, even though the older methods must be continued for some time.

The problem of laying out plants coming within this group is much more subtle than in plants of the manufacturing type. The provision of buildings and equipment, worked out in accordance with certain fixed assumptions, does not assure, during subsequent operation, the fulfilment of these assumptions because the physical layout does not indicate necessarily the desired plan of routing. It will lend itself to many less efficient but workable alternative plans, and the same is even more true of the performance of individual machines. It is particularly important that this condition should be recognized by those who will operate the property. It is an inherent fact that while such a layout as we are considering should prove, in the hands of experienced men familiar with its purpose, to be fully as efficient as anticipated, in the hands of others it will probably fall far short of the requirements.

M (2) A, B, C, D, E—RÉSUMÉ.

Owing to the great number of variable factors entering into the problem of laying out plants for heavy machine work of a given line, requiring, among other things, the establishment of certain assumptions concerning the manner in which the work will be handled after the plant is built, it is evident that the selection of equipment both as to character and amount cannot be accomplished with anything like the certainty that is possible for the manufacturing plant. Further, the character of the building is directly dependent upon conclusions reached concerning the equipment, and as these very conclusions are, to a certain extent, only an approximation, it will be seen that unless the best of judgment is exercised the most favorable solution in regard to the buildings proper will not be obtained.

The routing problem in shops of the second class is much more difficult of solution than in the first instance, and it is much more difficult to comply with the adopted plan than for manufacturing plants. In the first place, when laying out the shop, one cannot expect to secure uniform progress of materials through the plant and the result must necessarily be a compromise with a view to securing the best average routing of all the parts. In certain cases, it becomes necessary to consider carefully the advisability of installing additional equipment, rather than transporting the parts a considerable distance to points where equipment of the desired character is available. In such instances the handling cost must be weighed against the interest and depreciation charges incurred through installing additional machinery for convenience only.

A rearrangement of departments for the purpose of increasing deficient areas or changing the plan of routing can be effected quite readily, as a rule, in a manufacturing plant where the buildings are of uniform cross section and the equipment can be readily moved. Rearrangements of this kind, however, cannot be made with anything like the same facility or efficiency in the plant composed of various buildings designed for specific kinds of work. Therefore, we are confronted with the anomalous condition that for plants in which the requirements can be definitely anticipated, subsequent changes in departmental locations and areas are not likely to be necessary, although they can readily be made; whereas for plants in which the requirements cannot be so definitely ascertained, and the need of subsequent changes is thus more probable, the buildings must be specifically designed to comply with radically different kinds of work, which, of course, makes a rearrangement very difficult to accomplish.

The buildings illustrated on pages 166, 167, 168, and (in part) 164 are occupied by kinds of work that come within the second division of the classification, and it will be clear at once that the designs of the structures have been directly influenced by the character of work performed within them. Not only are the types of the various buildings quite different, but they also represent a wide range in cross-section dimensions. The total floor space provided in the shop of the Emerson Steam Pump Company, Alexandria, Va.,* is about equally divided between the area

* These buildings are shown on page 164.

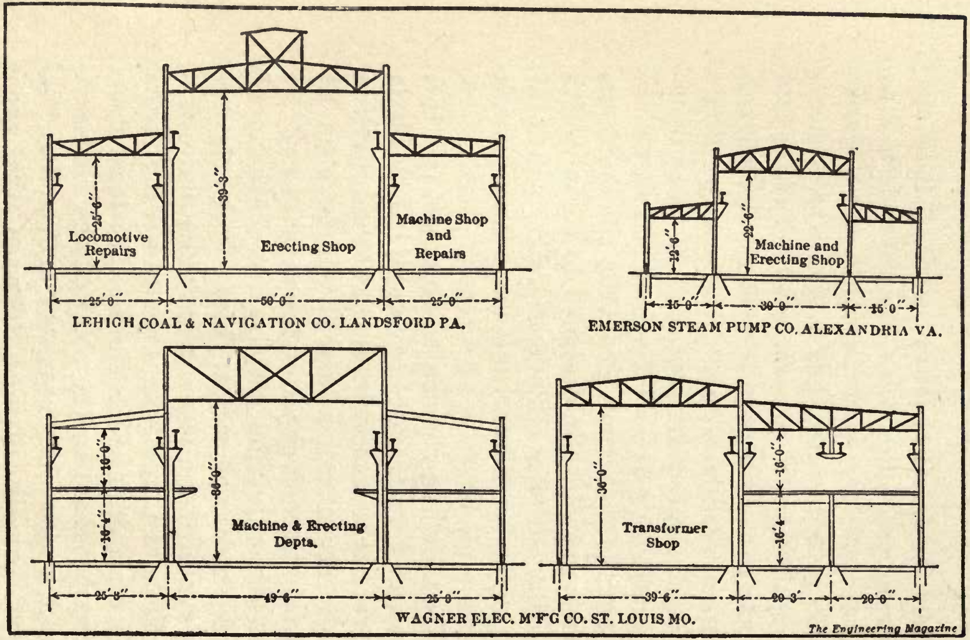


FIG. 10. THE LEHIGH COAL & NAVIGATION SHOPS BELONG TO THE THIRD CLASS—REPAIR AND JOBBING WORK; THE OTHERS, TO THE SECOND CLASS, OF SPECIAL MACHINE SHOPS.

served by an electrically operated crane requiring a relatively high headroom, and an area or areas over which light cranes can be run but where the headroom is such as to lend itself properly to the installation of overhead line shafting. The requirements imposed by the work performed in the machine and transformer departments of the Wagner Electric & Mfg. Company, St. Louis, (p. 164), were such that the areas under the high bays needed to be only one-third of the total floor space, so that the conditions were fulfilled by designing gallery shops as illustrated by the cross-sections. In both these shops the gallery construction possesses industrial advantages in addition to requiring only two-thirds the amount of real estate that would be occupied if the shops were single story throughout.

Frequently, the area in connection with which relatively high headroom is required is only a small part of the total necessary enclosed space. The main buildings of the new plant now being constructed for the Cincinnati-Bickford Tool Company, Oakley, Ohio, are shown in cross-section on page 166. It will be seen that a high bay is provided for the warehouse department, and one running

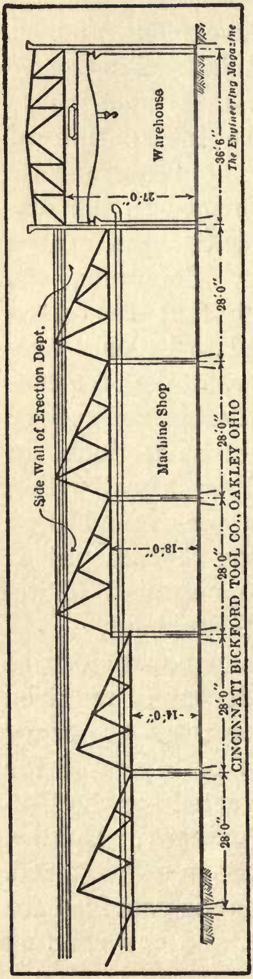


FIG. 11. A TYPICAL CONSTRUCTION FOR A PLANT DEVOTED TO MODERATELY HEAVY SPECIAL MACHINE WORK.

A high bay for the warehouse department, one perpendicular to it for erecting large equipment, and large saw-tooth roofed area for machining departments.

perpendicular will house the large equipment. The machining departments will be housed in a large area covered by a saw-tooth roof construction, two distinct clear heights being provided to accommodate different kinds of work. A cross-section, opposite, of two of the shops composing the plant of the Arthur Koppel Company, Koppel, Pa., illustrates the manner in which provision was made for the building of their output, which consists of contractors' dump cars, industrial railways, etc. The machine shop now being designed for Barnard & Leas Mfg. Company, Moline, Ill (page 168) is another interesting illustration of the manner in which certain special requirements have been fulfilled, and the proposed boiler shop of the Ames Iron Works, Oswego, New York, is another.

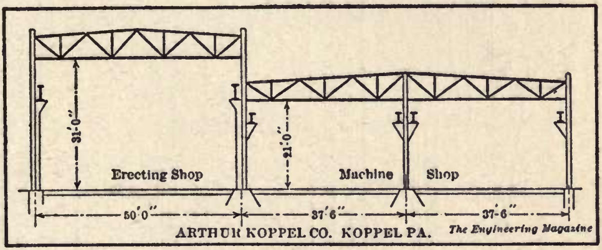


FIG. 12. A MACHINE-SHOP FOR MANUFACTURE OF CONTRACTORS' DUMP CARS, INDUSTRIAL RAILWAYS, ETC. SPECIAL WORK OF MODERATELY HEAVY CHARACTER.

GENERAL MACHINE WORK

We will now take under consideration the broad requirements imposed by metal-working plants that compose the third division of our classification.

M (3) a—MATERIALS—The character and amount of materials can be anticipated only in small part, owing to uncertainty of kind of work that will be done. Consequently, there is imposed a wide demand upon the receiving and stores departments.

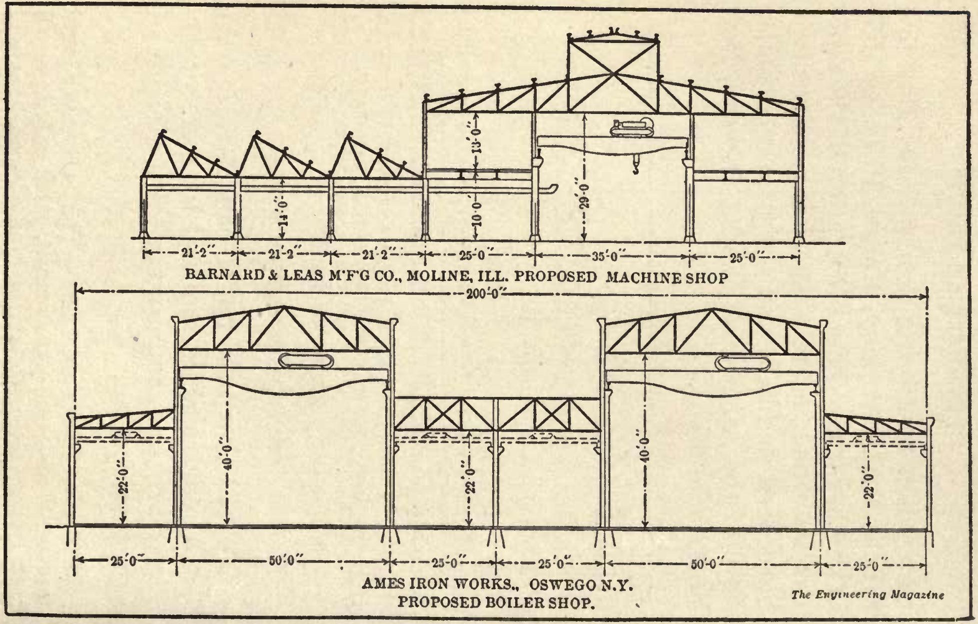


FIG. 13. PLANTS ILLUSTRATIVE OF ADAPTATION TO SPECIAL REQUIREMENTS OF MODERATELY HEAVY MACHINERY BUILDING.

The repair departments that must be operated by certain large industrial companies come within the group of plants now under consideration. The requirements that must be met in such cases are defined, of course, more clearly than is true for businesses that depend entirely upon jobbing work, but their administration is more difficult in one sense than in the latter case, because extraordinary demands upon the repair department are likely to develop when least expected. If the shop in question is the one set aside for making repairs upon the equipment of a large rolling mill, there will be performed certain routine work comprising the making of parts that must be regularly renewed, turning of new rolls, building of special auxiliary equipment, etc., but the department must also be so equipped and administered that it can handle expeditiously extraordinary repairs of practically any kind demanded by the business.

The raw-materials stores room for a shop of this kind usually contains two distinct classes of materials, namely, those provided for specific purposes such as duplicate machine parts, and various materials which can be used in connection with a variety of needs constituting the daily requirements of the shop. Each commission of this kind presents wholly special conditions, which it is quite impossible to define broadly with anything like the precision applying to the stores of manufacturing plants. In the latter instance the raw material is characterized by large quantities of comparatively small parts, for the storage of which very efficient means can be provided. In contrast with this condition, the materials that must be available in the stores room serving the repair shop are usually of the most diversified character. In certain cases, we find one, or at the most two or three, duplicate parts of very large size and weight, more duplicate parts of smaller size, and a comparatively complete line of miscellaneous supplies, there being, however, but a comparatively small stock of any one article or material. The large parts may absolutely necessitate the provision of special means for handling and transportation, but the bulk of the materials are such as can be handled readily without such assistance. When conditions are as outlined, the stores department can be laid out, however, with somewhat greater precision than is possible in a purely jobbing shop.

The very nature of the jobbing plant is such as to prohibit a close definition of either present or future requirements. The purpose in view is to prepare for as diversified a line of performance as is possible, but insofar as raw-material departments are concerned it is practicable to carry a permanent stock of only those materials that can be adapted to various uses. Provision must be made, however, for anticipated requirements imposed by the handling and temporary storing of the special materials that given orders are likely to cover.

M (3) b—Equipment—Principally stock machines suited to very wide range of work. Occasionally special machinery for possible repairs on special parts. Selection of types and determination of amount of equipment can be approximated only.

The ability to perform almost any conceivable job is usually the first requisite when selecting machinery. Therefore, the greater part of the equipment required for job and repair shops consists in standard machine tools, designed with a view to the performance of very wide ranges of work. If this plan is not followed a greater amount of equipment will have to be installed, part of which will stand idle a considerable portion of the time, thus imposing a heavy burden upon the business or department. Wide range of usefulness is usually accompanied by lower efficiency of performance, the efficiency being higher as the design of the machine aims towards singleness of purpose, and becoming a maximum in the full automatic types. However, it frequently pays to secure a wide range of usefulness even at the expense of efficiency, for the ability to perform a given job may be the vital factor, whereas the cost incurred may be secondary only. The lathe equipped with a two-spindle head stock and the boring mill that can be increased in capacity by moving the housings back are extreme examples. In actual practice many other procedures are of course resorted to for the purpose of accomplishing certain work, which procedures would not be considered good practice in plants of the second group. Instances are the use of a planer or slotter where a milling machine would do the work more cheaply, or the use of a milling machine in place of a gear cutter, or the performance by hand of certain operations that under other circumstances could be done more economically by machine. Consequently it is evident that the selection of machine-tool equipment for repair or jobbing shops is a matter in connection with which many questions other than efficiency of machinery must be taken into account.

Repair shops may impose more specific conditions, as for example in the case of a shop serving a large rolling mill, where it may be imperative to provide certain equipment that is designed particularly with a view to making repairs on large parts of the equipment, the breaking of which may be a remote possibility but so vital, if it does occur, that it is justifiable to have available at all times the means necessary to effect the repairs. Then, again, there is the equipment required to turn the rolls and do other single-purpose routine work.

M (3) c—BUILDINGS—The character of work to be done is usually a governing factor in their design. Precise definition of types and sizes is, however, seldom practicable.

The buildings or sections of buildings required for repair or jobbing work differ widely in character, depending upon the characteristics of the work to be performed. However, their design is governed by broad conditions which affect principally over-all dimensions in plan and elevation and also the floor loads. They have not the detailed peculiarities which are illustrated by the cross-sections of shops coming within the second group of our classification. The exception to this rule is presented by repair shops where definite requirements may be imposed by certain specific lines as previously referred to. As a rule, if the work that is to be handled is at all broad in its characteristics, there is required not only a section with considerable overhead room served by a traveling crane, but also an area with less overhead suitable for machine tools. Hence standard types of single or multiple-story buildings adapted to various classes of occupancy are not often adequate.

M (3) d—LABOR—Especially versatile in respective trades. Possibly not so capable at any one job as operators in shops of second class, but competent throughout a much wider range of performance.

The labor employed in repair or jobbing shops has the same broad characteristics as other factors that have been touched upon; namely, the various employees should be "all-around men" rather than specialists, and just as the all-around machine is not as efficient as the one designed for the performance of a specific job, so we cannot expect the versatile mechanic to attain as high an efficiency of performance as the specialist. The character of workmen required is a question that must be considered carefully by the engineer who is planning a new plant or extension, and also the status of the trades in question for the locality where the plant is to be built.

M (3) e—ADMINISTRATION—The system of management should be the one that will prove most effective under the circumstances that make it impossible to anticipate exact conditions from day to day. Each case must be worked out along special lines and often conditions are such as not to justify a highly perfected system.

The administration of all industrial plants should be based upon the same fundamental principles, irrespective of the nature of the work performed, but the details of the administrative system may differ materially for each of the three groups in our classification, and, in fact, must be varied for different plants coming within the same group.

The primary condition that must be dealt with in connection with a manufacturing plant is the one presented by an output made up of comparatively small articles turned out in large quantities and sold from stock; therefore, the work can be planned considerably in advance and with a very great degree of exactness. The repetitive nature of the work permits of the establishment of definite standards for the manufacture of the entire output, which standards when established are adhered to until the experimental departments have devised more efficient means.

Plants belonging to the second group possess the characteristics just referred to only in part. While all the output may be built in accordance with stock orders, the trade requirements are frequently such that it is not practicable to carry a very large number of duplicate units of the product. Standard methods of doing the work have to do more with the performance of detail operations than work upon the parts considered as a whole. The nature of the equipment employed must be such as to make it much more flexible, insofar as its uses are concerned, than is necessary in the manufacturing plant. Efficient performance requires, as a regular function of the administrative system, one or more specialists whose duties consist in the preparation of definite instructions covering the manner in which the various operations must be performed, taking into account the exact means that will be available.

The pronounced characteristics of the jobbing or repair shop are that it is practically impossible to plan the work as a whole for a considerable period in advance, nor is it possible to establish fixed methods of performing certain jobs of like character which may be received at odd intervals, as the necessity for completing such jobs in the least possible time may require somewhat different procedure in each case owing to the demands of other work that is being handled. Effective administration of shops comprising the group in question must necessarily be accomplished through a system permitting of very great flexibility, and there is required a degree of personal contact between the executive head and the shop superintendents that may not be desirable or practicable for plants in the first or second group. Each case must be worked out along special lines.

M (3) A, B, C, D, E—RÉSUMÉ

It is obvious from the foregoing that plants for businesses or departments coming within this group can be laid out with the least precision, as compared with those composing the two groups formerly considered. The equipment must be selected with a view to a wide range of performance rather than to the manufacture or building of a certain character or volume of output.

This wide range of usefulness, rather than the attainment of high economy of single operating, is usually the ruling factor. Occasionally the need of certain definite work requires the installation of special machines. The type of buildings must be based upon certain broad requirements, and to the extent that large and heavy work is handled they are special in character. Administration methods must be suited to comparatively uncertain conditions, and while in one sense such conditions call for the most highly perfected system, there may be incidental reasons which prohibit or do not justify their introduction. In any case the system must be one which operates from day to day.

While the foregoing discussion regarding repair and jobbing shop is too general in character to be of direct value to the engineer who is engaged upon the planning of a given shop, yet he will find that the solution is more readily attained if he himself and those with whom he is co-operating have a correct realization of the limits of the problem as compared with those presented by shops for work that belongs to the first two groups.

The shop of the Lehigh Coal & Navigation Company, illustrated on page 164 was designed primarily to handle repair and jobbing work. One of the side bays is provided with a drop pit and an overhead traveling crane that are used in connection with the repairing of standard-gauge locomotives. The other side bay is used in part for machine work and in part for the repair of narrow-gauge locomotives of the steam and electric types. The main bay of the shop is occupied by the large electrically driven machine tools and the department for the performance of miscellaneous repair work upon pumps, engines and general mine equipment. There is also a certain amount of new machinery built in this shop.

As previously stated, it is usually found that the requirements presented by a given metal-working business do not fall wholly within the clear confines of any one of the three divisions making up the classification, although in almost every case there is a predominating tendency toward one of them. If this happens to be the first division, a definite and clear-cut solution should be expected; if the second division, the solution will not be as clearly defined and the selection of equipment, its arrangement, and that of the departments, will represent but a compromise of the to some extent conflicting requirements imposed by the diversified kinds of work; if the third division, the solution is usually but an approximation, as it must be worked out from comparatively meagre data.

Chapter IX

MACHINE SHOPS AND THEIR SPECIFIC REQUIREMENTS

THE preceding chapter dealt with certain of the broad characteristics of metal-working plants; consequently the discussion was more specific than the treatment accorded our subject in the chapters that preceded it. It is now proposed to exemplify the knowledge of details of the most specific character which must be possessed by the engineer who undertakes the planning and arranging of industrial plants, limiting the consideration to certain features of machine-shop practice as they follow logically upon the questions last considered.

The primary object when arranging or planning a machine shop is to provide for the most efficient performance of different kinds of work upon definite amounts of various materials, so that the characteristics of the resulting plant shall be the direct outgrowth of a detailed definition of all of the factors incident to the execution of such work. This includes, of course, a thorough understanding of all of the broader requirements which have been touched upon in the preceding chapters, such, for example, as the routing problem.

The machine-shop problem considered in its most elemental sense resolves itself into one of removing chips from the parts upon which the work is to be done. This is equally true whether we consider a lathe tool removing a heavy turning from a locomotive tire or a file smoothing a metal surface, an emery wheel cleaning up the face of a casting or a scraper putting the finishing touches on the shears of a lathe. Tool steel is used for by far the greater amount of work, so it should be expected that any marked improvement in its composition or method of treatment, making possible the removal of a greater quantity of chips in a given time, would result in many radical changes in machine-shop methods and consequently in the characteristics of machine shops. The results secured by the application of scientific methods are admirably shown in Mr. Fred W. Taylor's classic work upon the art of cutting metals. Mr. Taylor's discovery of a new method of treating certain alloy steels, which has resulted in the perfection of vastly more efficient cutting tools than formerly existed, is now too well known to require explanation.

Machine-tool equipment in use when the high-speed wheels were introduced proved so unsuited for the new demands that it was soon found that no halfway measure would be sufficient, but that it was necessary to reconsider immediately the whole subject of metal working from an entirely new standpoint. Just about this time the motor drive was being strongly advocated by the manufacturers building such equipment, and it was evident, almost from the start, that the individual motor drive for machine-tool operation promised a satisfactory solution to the new problems of greater power and better speed regulation. The perfection of the motor as well as the tool steel had come about through the application of thoroughly scientific methods of investigation and deduction, and when the leading machine-tool builders applied these same methods to their work there resulted, in a comparatively short time, a close competition for supremacy between the tool steel on the one hand and machine tools on the other.

Prior to this time much had been done toward perfecting methods for administering machine-shop work, as is attested by the work of Mr. Fred W. Taylor, Mr. H. L. Gantt and others. The true import of this work was not appreciated by shop managers generally, however, until they were confronted with the wide differences existing between the amount of work that could be accomplished in connection with the modern equipment when operating under test conditions and the figures of *average* results secured in their shops with the same kind of equipment.

The engineer who is not thoroughly conversant with the present high achievements in both the physical and administrative departments of machine-shop practice, is wholly unqualified for laying out, designing, and building machine shops capable of the highest efficiency now securable. This is particularly true as the use of scientific methods has resulted in a development which has been so fruitful of results that it may be said that machine-shop practice is, in many of its more important aspects, approaching a stage of standardization. By this I do not mean that important advances in connection with many of the details that enter into machine-shop practice will not be made, but rather that the full benefits to be derived under the present status of the art have been made available through scientific analytical study and logical deduction.

The starting point for standardization is always in the tool room and properly begins with the cutting tools. The adoption of standard shapes and sizes for lathe tools, boring cutters, and chisels is now the general practice, as is also the method of forging and treating the tools. Even in small shops it pays to have one man grind all the tools, absolutely prohibiting the workman access to any grinder for this purpose. The steel is now bought by several large users according to specifications, different compositions being specified for different classes of tools, and it is likely that this practice will become standard.

While what has just been said regarding cutting tools is now generally appreciated and acted upon, the same careful attention is not given to many other accessories which rightly form a part of the tool-room equipment. All kinds of bolts and blocking should be standardized. In certain shops it is now

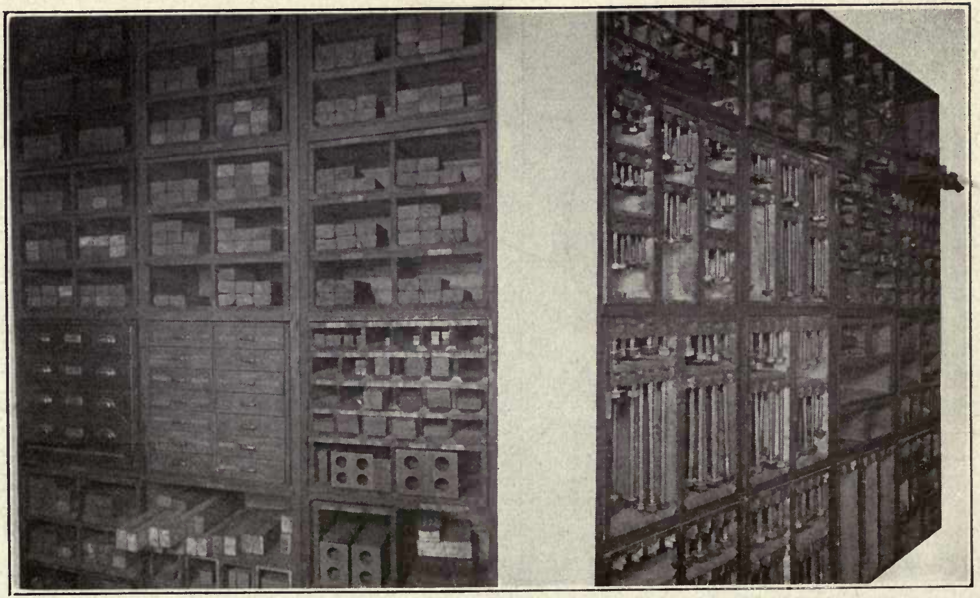


FIG. 14. SECTIONAL RACKS, TOOL ROOM OF THE TABOR MANUFACTURING COMPANY, PHILADELPHIA. On the left are seen the wood clamp blocks and on the right the bolts, etc., standardized for each job and methodically kept in place and in order.

the practice always to issue with a set of bolts a standard wrench exactly fitting the nut. When these bolts are returned to the tool room each one is examined to see that it has not been damaged and that the nut is hand-loose, and if this is not the case the parts are not returned to the racks until they have been repaired.

It is customary in large machine shops to use tool rooms for storage purposes only, all grinding and tool making being done in a separate department, which in some cases is not fenced off from the rest of the shop. The desirability of this plan, as well as many other common procedures, depends to a considerable extent upon the number of men employed and the character of the work. The function of the tool room, however, is always the same; and to preserve it properly it is necessary to draw a sharp line between the making, caretaking, and issuing of tools, and the productive work in connection with which the tools and accessories are used.

It is hardly necessary to call attention to the important bearing that all the questions pertaining to tool-room practice have upon the work of arranging and planning machine shops. They govern in part the character and amount of tool-making equipment and its location—the character and amount of small tools which must be accommodated in the tool room proper—and indirectly they have, of course, a fundamental bearing upon the entire machine shop. A development in the line of standardization is exemplified by the sectional racks which have been designed for the storage of small tools. Such racks are illustrated in Figures 14 and 15 which are views in the tool room of the Tabor Manufacturing Company, Philadelphia, Pa. It will be noted that special receptacles are provided for such parts as cutting tools, bolts, wood clamp blocks, and other auxiliary equipment which until recently were not standardized or carried in the tool room.

A very interesting example of the standardization of the lathe and planer tools on a large scale is the central tool-dressing plant, recently established in the Philadelphia Navy Yard, which supplies to all navy yards on the Atlantic Coast high-speed lathe and planer tools that have been forged, treated, and ground to standards. Each of the various yards is equipped with an automatic grinder for regrinding the tools until they require redressing, when they are returned to the cen-

FIG. 15. SECTIONAL RACKS FOR ARBORS, BORING BARS, CUTTING TOOLS, ETC.
Tabor Manufacturing Company.

tral tool-dressing plant at Philadelphia for replacement by newly dressed tools. The great advantages of this scheme are that all yards are equipped with tools of standard shapes and of uniformly high quality, and as the forging, dressing, and grinding of tools are done in large lots, substantial reductions in cost result. This system for the standardization and distribution of tools was introduced in the Philadelphia Navy Yard by Mr. H. K. Hathaway, and it set an example that will probably be followed by railroads and other large concerns operating a number of machine shops.

Of course, the standardization of a considerable part of the small-tool equipment can be accomplished only after the detailed methods of performing the shop work have themselves been standardized. It is in this regard that scientific management plays such an important part, for it is possible to define the most economical manner of performing each individual operation only after "time study" (which is a part of the type of management referred to) has resulted in the acquisition of a knowledge of all details. As a matter of fact, the establishment of standard shapes for tools came about through such study;

and many other instances could be cited where the results of scientific research are made available through their incorporation in automatic machinery.

The characteristics of different classes of large machine-tool equipment have been referred to previously, but as a detailed consideration of this important division of machine-shop practice would require the utilization of much more space than I have available, I will not attempt to take up individually the various interesting types. I will merely refer to some of the most important considerations pertaining directly to or closely allied with machine-tool equipment which confront the engineer who is arranging or planning a machine shop. These will be brought out in connection with a study of the individual motor drive and by certain brief allusions to methods of administering machine-shop work.

The driving of mechanical-tool equipment by individual motors will be taken up rather fully, for its consideration illustrates particularly well the kind of scientific studies which it is the purpose of this chapter to exemplify, and further, the subject is itself one which, on account of its wide application, frequently confronts the consulting engineer. While the discussion relates specifically to metal-working plants, many of the conclusions are so broad as to apply equally to the driving of other kinds of equipment, and, as already pointed out, considerations of equipment and construction are closely interlocked.

Generally speaking, it is conceded that the proper drive for machine-tool equipment is the electric motor, but there is some difference of opinion as to the extent to which the individual or group methods of driving should prevail. While it is the purpose of the discussion that follows to point out a method for determining this question in each case by a detailed analysis of the problem, yet it will not be out of place to state that the results of such study in connection with a great number of machine shops indicates conclusively that usually the requirements are properly met only through resorting in part to the individual drive and in part to the group drive. The principal advantages offered by the individual motor drive are, no doubt, generally familiar to the reader, so it would not be necessary to include the following discussion were it not my object to display thereby the proper method of attacking such problems. The course of reasoning followed in this instance is but typical of the regular procedure adopted by the capable industrial engineer.

The broad considerations bearing upon the individual motor drive for machine tools are illustrated in Figure 16. This chart is presented only for the purpose of showing how far-reaching is the subject with which we are dealing, and is of value only insofar as it indicates the scope of investigation required. Certain broad characteristics of the requirements of the machine-tool drive can be classified under the three subdivisions of metal-working plants referred to in the preceding chapter. For example, machine equipment suitable for manufacturing work is usually designed with a view to a comparatively small range of adjustment, so necessitating the simplest conditions insofar as drive is concerned, namely, constant speed operation of the motor. In shops classified under the second heading little opportunity exists for duplication in the sense just referred to. The machines must handle a variety of work, and even those purchased for the performance of specific operations are usually suited for other purposes so that they may be kept busy the greater part of the time. Variations in

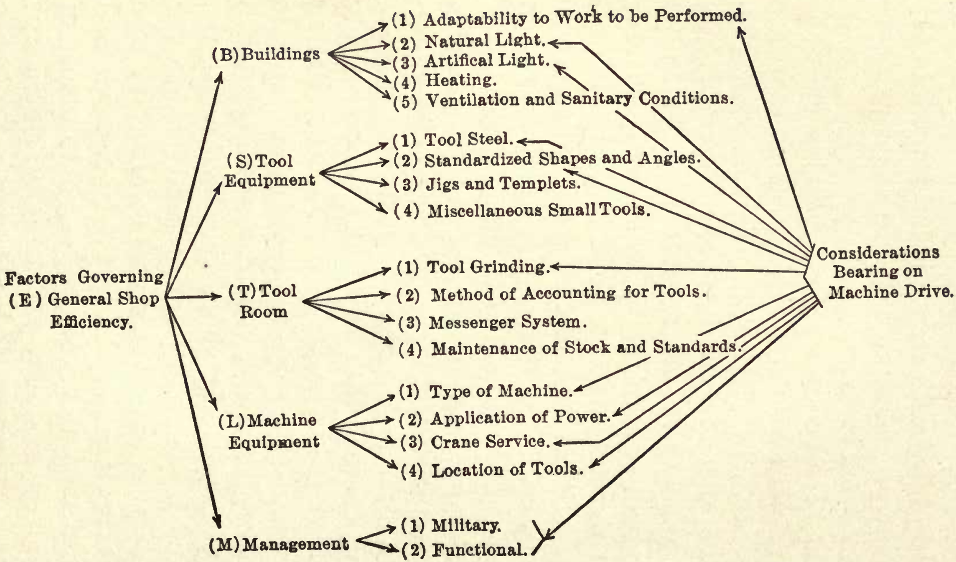


FIG. 16. SHOP CONSIDERATIONS BEARING UPON MACHINE DRIVE.

size of work, materials, and cutters demand an adjustable-speed* drive together with change feeds if most economical results are desired. This is true to a still greater degree of machines used in shops of the third class.

Such an analysis as has just been given is wholly inadequate, however, for the purpose of solving the drive requirements presented by machine tools operating under certain established conditions. In order to accomplish this result the problem should be analyzed in substantially the manner outlined below. I do not wish to create the impression, however, that I consider it necessary to analyze the subject in this way in each instance, for the work that has been done by the leading tool manufacturers who have conducted extensive experiments in connection with the machines they build has rendered such a course unnecessary except in isolated cases.

Machine-tool-drive requirements can be studied advantageously in connection with the charts given below. Figures 17 and 18 relate to the different *characters* of load imposed upon machine tools necessitating re-

*The words "adjustable speed" were proposed by the writer before the International Electric Congress of 1904 as more accurately describing the condition of operation than the words "variable speed," and this term has since been generally adopted.

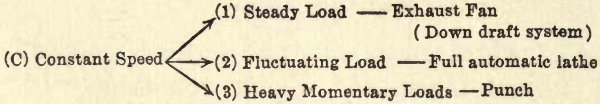


FIG. 17. CHARACTERS OF LOAD, CONSTANT SPEED DRIVE.

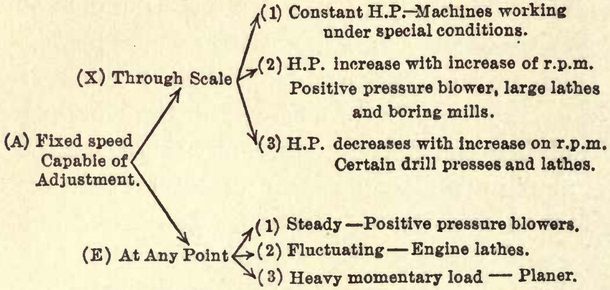


FIG. 18. CHARACTERS OF LOAD FOR ADJUSTABLE SPEED DRIVE.

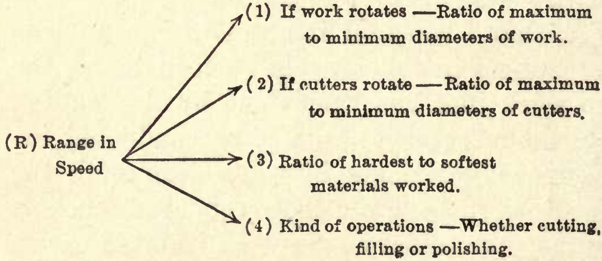


FIG. 19. FACTORS THAT INFLUENCE RANGE IN SPEED.

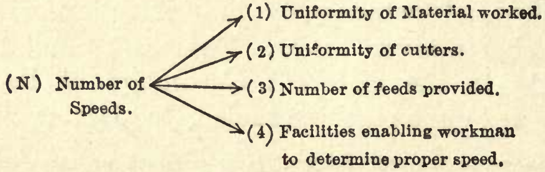


FIG. 20. FACTORS INFLUENCING NUMBER OF SPEEDS.

spectively the constant-speed and adjustable-speed drive. Figure 19 is an analysis of the factors determining the range in speed, and Figure 20 the factors governing the numbers of speeds for the adjustable speed drive in connection with machines using cutters. In other words, the condition that it is necessary to establish in connection with the constant-speed drive is the load curve to which the motor will be subjected, whereas with the adjustable-speed drive we must determine the range from minimum speed to maximum speed and the number of operating speeds within this range, and then we must know just what the load curve will be for each.

Adjustable speed may be desirable on grinding machines, depending upon the ratio of maximum to minimum wheel diameters and other matters that must be considered separately in individual cases. Machines for punching and shearing, while usually arranged for constant speed, frequently require an adjustable-speed drive. For example, assume a punch operating at twenty-eight strokes per minute; the operator may have work of such a character that he can easily punch a hole each stroke, while in another case, because of heavier sheets, or greater ac-

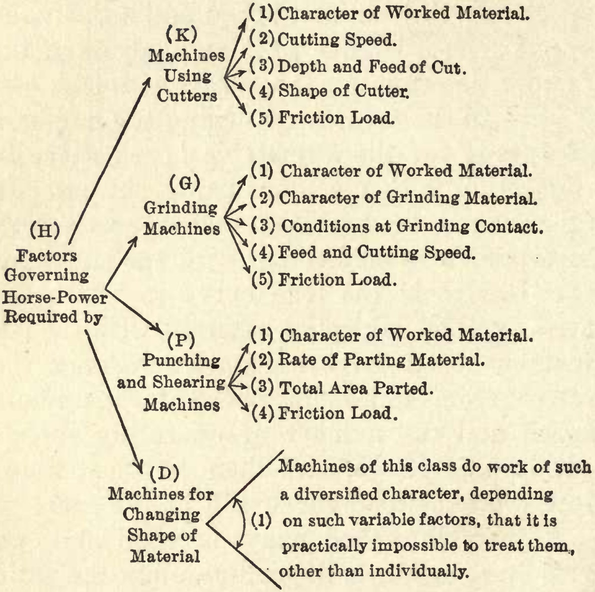


FIG. 21. FACTORS GOVERNING HORSE POWER REQUIRED FOR DIFFERENT TYPES OF MACHINES.

curacy required, he is compelled to skip every other stroke, so punching but fourteen holes a minute, while if the machine would permit he might readily do twenty-two. Such a saving on this class of machinery often yields a large actual return, as the time required for setting up or making ready is usually small.

The amount of horse power required for machines of different types depends on the factors given in Figure 21.

The principal items to consider when designing or selecting machine drives have been given, but to explain more fully the line of reasoning that should be followed, let us assume definite conditions, and consider the equipment needed to fulfil them. The letters and numbers given below refer to the charts.

EXAMPLE.

LATHE A-B for general work in shop of Blank & Co., manufacturers of air compressors.

General features of this plant and its organization that influence type of drive (see Figure 16).

E.B.-1. The machine under consideration is to run in an old plant, so no saving in cost of buildings could be effected by type of drive.

E.B.-2. The natural light at the point where the lathe is to be located is very poor, so it is important not to obstruct it any more than absolutely necessary.

E.B.-3. Artificial light has in the past been supplied by an independent company, but they desire to install a power plant that will take care of this feature as well as power. It is desirable to depend largely upon general illumination by arc lamps with incandescent lights for detail work.

E.S.-1-2, and E.T.-1. For roughing work the best alloy steels, forged, treated, and maintained by special department, assuring uniformity and high efficiency, will be used.

E.L.-1, 2, 3, 4. Character of work necessitates constant use of power crane, making overhead belting and fixtures objectionable and difficult to provide for on account of location in main bay of shop. As cost of power in this plant amounts to less than 3 per cent of total cost of product, it is not a determining factor in character of drive.

E.M.-2. The type of management being introduced at this plant should ultimately assure intelligent direction of work and proper use of equipment.

Referring to Figure 18:—

(A)-X-1-F-2. Majority of work (probably 80 per cent) will be steel and gray-iron castings between 18 in. and 48 in. diameter. Maximum conditions call for removal of same amount of metal between these limits, and approximately constant cutting speed. Maximum horse-power requirements are consequently constant through the range, but subject to fluctuations at any one point below the said maximum.

Referring to Figure 19:—

R-1. At times it will be necessary to machine work as small as 10 in. in diameter, or as large as 60 in. diameter; consequently a range in speed of 6:1 would be required for this purpose.

R-2. Cutters will always be stationary.

R-3. The ratio of hardest to softest material required by specification will be approximately 2:1. This will increase the necessary speed range to 12:1.

R-4. The majority of work will be roughing and finishing with cutters. Some filing and finishing with emery cloth will, however, be necessary and for this purpose experience would dictate a cutting speed of 150 ft. per minute on 10 in. diameter. It will be necessary to provide a cutting speed of 15 ft. per minute on the largest diameter on account of the frail character and difficulty of driving some of the castings to be machined. Total range of speed is determined by limiting conditions of a cutting speed of 15 ft. per minute on 60-in. work and 150 ft. per minute on 10-in. work. I have purposely chosen these extreme conditions to illustrate my point better. In practice a 60-in. lathe is seldom required to run at 57 r. p. m.

$$\frac{150}{\frac{10 \times 3.14}{12}} = 57.3 \text{ r.p.m.}$$

$$\frac{15}{\frac{60 \times 3.14}{12}} = .955 \text{ r.p.m.}$$

Consequently, for all practical purposes, the face plate of the lathe should run from 1 r. p. m. to 57 r. p. m.

Referring to Figure 20:—

N-1. It was stated above that the character of material would vary in the proportion of 2:1, this being a requirement of the products manufactured. Uniformity of material, or how nearly the requirements can be attained under shop conditions, is one of the factors influencing the number of face-plate speeds. A fully-equipped laboratory, under the direction of an able chemist, assures a much more uniform product in the plant in question than is usually the case. A great deal of experiment and investigation is necessary before definite assertions can be made in this direction, but castings from the same pattern should not vary more than 20 per cent.

N-2. Cutters of the character indicated above (E.S.1) should not vary in efficiency more than 10 per cent.

N-3. The full consideration of this point involves an understanding of the laws governing speed, feed and cut for various materials. It will not be practicable to include here full data on this detail. Hundreds of tons of steel and cast-iron have been cut up to determine these relations, and constant experiment is necessary to keep abreast of rapid improvements. I will only say that it is quite as necessary to provide an adequate number of feeds as it is spindle-speeds, and in fact a limited number of either one of these factors will give efficient results provided a very close regulation can be had on the other.

In the present instance it was not considered advisable to specify changes to the standard feeding mechanism, as this feature had been well taken care of by the builder.

N-4. As the operation of the machine is ultimately governed by the facilities at the disposal of the machinist who runs it, it is absolutely essential that this point be given most careful study. It involves practically every feature of shop system and management, and it is only under such systems as that developed by Mr. Fred W. Taylor, of which functional foremanship is but a single detail, that the conditions as outlined above can be fulfilled. It necessitates that the operator of the machine be informed as to the character of the material, efficiency of the cutter, proper cutting speed in consideration of duration of cut, and many other equally important factors.

So it will be seen that we cannot arrive at any data which would enable us to specify positively the number of spindle-speeds required. Our conclusions must necessarily be based principally on experience in shop practice, and for this reason engineers differ widely in their views. For the example under consideration speeds increasing in increments of 15 per cent are, in our estimation, quite as close as can be used to advantage. It is well, however, to err on the safe side, providing too many speeds rather than too few.

Referring to Figure 21:—

H-K-1, 2, 3, 4. Maximum permissible cutting speed on steel castings will be 60 ft. per minute; on gray-iron castings 60 ft. per minute (determined by actual requirements on a large variety of work). Maximum cut, cast-steel, 3/8 in. deep, 1/16 in. feed; gray-iron, 3/8 in. deep, 1/16 in. feed. (These conditions are established by character of work.)

The experiments oonducted to determine the laws governing speed, feed and depth of cut, for various materials refered to above (N-3) have been made available for purposes of design by means of slide rules, based on the derived empirical formulæ.

For the depth of cut and feed under consideration (cast-steel) the calculated pressure on the tool would be: 5550, or horsepower required:

$$\frac{5550 \times 60}{33,000} = 10.1 \text{ hp.}$$

H-K-5. The friction load can only be arrived at through experience and depends not only on the machine, but on the character and method of driving work. Experimental data on machines quite similar to the one under consideration would indicate 3 horse power through the entire range as sufficient to allow for this purpose. These conditions are plotted in Figure 22.

It will be noted in Figure 22 that the horse power falls off on either side of the working part of the scale. While it is easy to theorize as to the horse power required for work of various diameters, in actual practice the conditions are about as shown. It must be borne in mind that the machine under consideration should be primarily adapted for the majority of work that it will handle. We have assumed that 80 per cent of this will be between 18 inches and 48 inches in diameter, so that work outside of these limits is the exception.

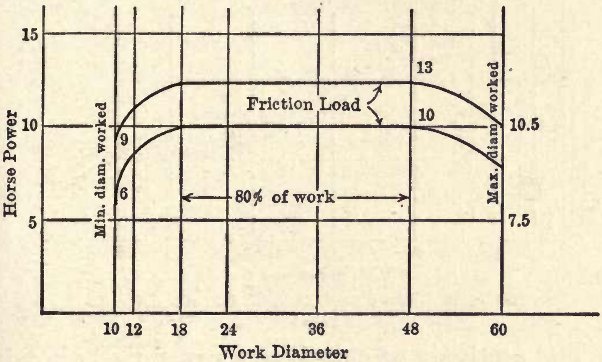


FIG. 22. RELATION BETWEEN MAXIMUM HORSE POWER AND WORK DIAMETER OF 60-INCH LATHE.

On small work, such as would be handled by this lathe, there is not likely to be opportunity for as heavy roughing cuts, and castings over 48 inches in diameter cannot be swung over the carriage, nor would it be good policy to aim at high efficiency at this point for the additional cost would not be justified by the saving effected on such a small fraction of the total output.

As the horse power between the working limits shown above was figured for the maximum cutting speed of 60 feet per minute, we can plot a relation between revolutions per minute and horse power. (See Figure 23.) The selection of electrical equipment for this lathe will be taken up further on.

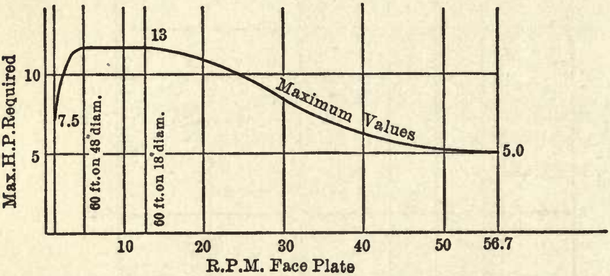


FIG. 23. RELATION BETWEEN HORSE POWER AND R.P.M. FOR 60-INCH LATHE.

The analysis of conditions presented above is, as was stated, essentially a problem for the machine builders to work out—in other words, the electrical companies should look to them for specifications covering the requirements to be met by their motors and controllers, and the consulting engineer should expect to find the entire problem properly solved through this co-operation.

We will now depart for a brief period from our illustration to consider the electrical phase of the subject. I will assume the following conclusions have been established:

1. Machines of present design, for comparatively small work, requiring constant-speed drive, should in most instances be grouped and operated from motor-driven line shafts. Specifications for new machines for such duty should be made with a view to special requirements. Indirect savings in one plant may much more than offset additional cost of constant-speed motor on each machine, while this would not be true in another.

2. For group driving, both direct and alternating-current motors give thoroughly satisfactory results. In either instance, if properly installed, repairs should not be an important feature. In certain industries—textile mills for example—the induction motor has decided advantages on account of close speed regulation with varying loads and lessened fire risk, but for machine shops these features are unimportant.

3. Mechanical means of speed control, including step cone pulley and variable-speed countershafts, while suited for many cases, do not always meet the requirements of machine drive. An attempt to obtain all the necessary speeds by gearing, for example,

is not only costly (if a sufficient number of changes are provided) but inefficient in that, as a rule, the machinery must be stopped to change from one speed to another, and cannot be controlled from an independent point.

4. For adjustable-speed work, direct-current motors of some one of the field-weakening types are now used almost exclusively. It is hardly practicable to secure by this means a range greater than 6 to 1, while in the majority of cases the most economical results are attained by not exceeding 3 to 1. In other words, it is necessary, in most instances, to resort to a combination of mechanical and electrical control, the disadvantages of each method being largely eliminated by this means. For example, even where machines are handling a very general line of work the greater part of it will be covered by a range of 3 to 1, so that if this amount is obtained electrically gear changes will be seldom necessary, and at the same time a comparatively inexpensive motor may be used.

5. Long transmission lines may make alternating-current desirable, and for certain extended plants the best results can be obtained by its use, together with motor generator or rotary convertor for direct-current

variable-speed motors. If, however, but one kind of current will be available, decision should be largely governed by the number of individual adjustable-speed drives required. In many instances, while group drives may be desirable at the start, new equipment should be purchased with individual motors for the sake of adjustable speed and ease of control.

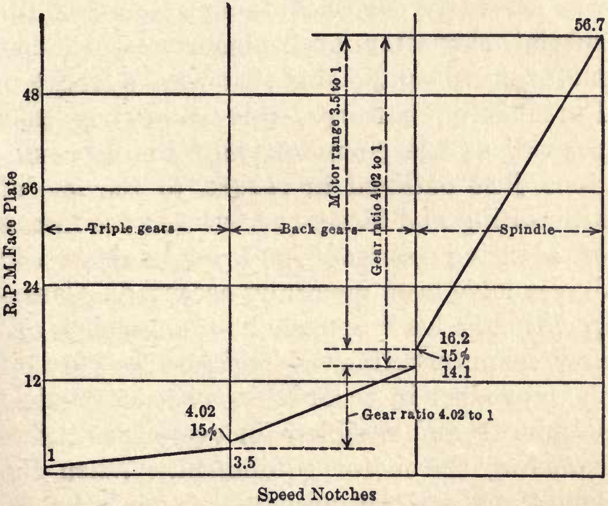


FIG. 24. SPINDLE SPEED FOR 60-INCH LATHE.

Returning to the 60-inch lathe considered above, the total speed range of 57 to 1 can be covered by the usual triple-gear arrangement, with the resulting ratios shown on the chart, Figure 24, the range in motor speed being 3.5 to 1.

During the period of development of the direct-current adjustable-speed motor and when machine tools were being redesigned to meet the requirements of the high-speed steels and to keep pace with the rapid advancement of the motor drive, this subject was seriously complicated on account of the special character and numerous types of motor-drive equipments that were advocated. Fortunately, however, this stage has been passed, as the comparatively simple conditions just outlined in regard to the use of alternating and direct current and the means of securing constant and adjustable-speed drives have been generally accepted. Consequently, the leading machine-tool builders are now manufacturing a considerable part of their product in accordance with established standards and complete in every particular including the motor equipment. When the conditions call for adjustable speed the direct-current motor of the field-weakening type operating on approximately 230 volts is used, and such equipment seldom requires any special provision upon the part of the purchaser, as direct current at 230 volts has been generally adopted by establishments using the character of machine-tool equipment in question. No doubt special conditions will arise from time to time which can be most efficiently met through the adoption of a three- or four-wire voltage system, but this will only be in special cases.

This discussion could be logically extended to include the mechanical and electrical characteristics of different types and makes of motors, controllers, and auxiliary apparatus, but as I believe that I have gone into the subject sufficiently to exemplify that kind of detailed specific knowledge which, in the final analysis, governs the character and extent of industrial plants, I will not take up this phase of the machine-shop problem.

If the lathe which we have chosen as our illustration were equipped with a field-weakening interpole adjustable-speed motor, the relation between motor horse power and that required by the machine in order to fulfil the conditions satisfactorily, would be approximately as shown in Figure 25. This curve is based upon the use of a motor weighing 1,615 pounds and which will deliver 10 horse power between a range of 350 r. p. m. and 1,050

r. p. m., or a motor weighing 2,300 pounds, which will deliver 10 horse power between 225 r. p. m. and 900 r. p. m. Either motor would prove satisfactory, although the larger one would assure more satisfactory commutation.

It is not sufficient for the engineer who is engaged upon the laying out of a large machine shop to base his conclusions alone upon the technical considerations which have just been presented. These should guide him in part in connection with the selection of the types and sizes of equipment, but these matters as well as the amount and arrangement of the equipment must be governed in the final analysis by the manner in which the plant is to be administered. When the character of work can be performed by full automatic machines, the problem is of course greatly simplified as the design of such machines predetermines the output to an extent that is not true of non-automatic machines. In other words, the results of repeated tests conducted by the builders of the former class of equipment are to some extent made available automatically to the users of such equipment. The maximum efficiency of machines which are not automatic and are designed for a considerable range of work can be secured only through the use of specific instructions concerning every detail in regard to the manner of performing the work, and such instructions can only be prepared after the accumulation of a vast amount of data based upon exhaustive "time study."

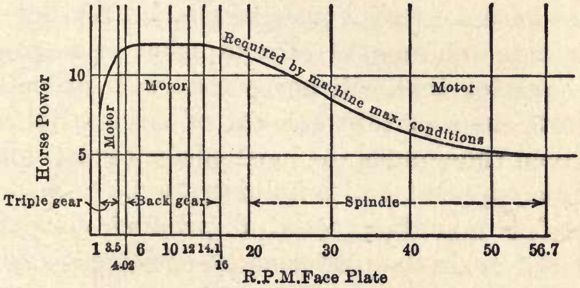


FIG. 25. DATA RELATING TO SINGLE-VOLTAGE FIELD-WEAKENING MOTOR EQUIPMENT.

Much has been done, however, toward making a considerable part of such information available to all, as is evidenced by the slide rules which have been made by Mr. Carl G. Barth, and the work of others who have specialized on this subject. These slide rules enable the ready determination of the proper cutting speeds and feeds for the performance of certain definite operations upon given materials in connection with the use of predetermined machines equipped with standard tools. The time required for the completion of each machining operation, when conducted in accordance with the plans just referred to, is also accurately predetermined by means of these slide rules, but of course their use is predicated upon the establishment of standards in connection with all the factors involved. So here we find a precise method for determining the amount of equipment of a given character that will be necessary in order to turn out a certain amount of work within a given time under the most efficient conditions of equipment and administration.

The manufacture of a product consists, however, in the performance of a great variety of operations, and in this connection it is also necessary to resort to "time study" in order to gain complete knowledge concerning all collateral operations, such as the handling of materials, the proper sequence in which operations should be conducted, and so on. The time consumed in getting ready for the performance of certain work, as well as the time required to move the product from machine to machine, and also the performance of work in connection with which machine-tool equipment plays a minor part or is not used at all (such as the assembling of parts), is in all cases a very important factor, often amounting in the aggregate to more than the total time consumed for the actual machining work. It is on this account that the old practice of each machinist personally securing from the tool room the tools and other auxiliary equipment, that in his judgment are needed, is rapidly giving way to the system of providing in advance, for each operator, all the tools and other parts that are required to consummate the work in a predetermined manner. The advantage of this method is so great that to some extent at least it is being followed in almost all large shops, even though standard instructions for performing the work are not given to the workmen or in fact may not be a matter of record.

This is a phase of the subject which must be most carefully considered when rearranging an existing shop or planning a new one, for the degrees of proficiency which have been attained by different companies in the administration of work vary widely. Consequently, the industrial engineer must base his work upon conditions as to administration which it is reasonable to expect will be fulfilled.

I have referred to scientific management, principally insofar as it provides the conditions of maximum efficiency as represented by the physical features of machine shops. However, an equally important function of scientific management is the training of individual operators in order that their efficiency may be brought up to what has been predetermined as a proper performance. It is one thing to lay out and design a machine shop in which the work will be performed by operators so trained, and a totally different thing to lay out a machine shop in which the work will be conducted by machinists who will be accorded every facility insofar as the equipment itself is concerned, but who have not had the advantage of this kind of training. Obviously this training must have as its object the accomplishment of a predetermined result, and this result can represent a high standard only if the work is conducted in accordance with certain fundamental principles of administration which experience has proved to be correct. It must ever be borne in mind by those who wish to obtain a position of proficiency in regard to the laying out of industrial plants, that the problems of equipment and administration must be considered jointly. The correct solution of either one of these factors is quite impossible without a full recognition of the conditions governing the other.

The readers of Mr. H. L. Gantt's book entitled "Work, Wages and Profits" will appreciate, I am sure, the bearing that scientific management has upon the work of planning and designing machine shops or other industrial plants.

CHAPTER X

MODERN INDUSTRIAL PLANTS

THE preceding chapters have dealt with the "method of procedure" that should be followed when planning and designing industrial plants. Attention has been directed especially to the physical requirements which are common to the efficient operation of all plants (irrespective of their output) and it has been shown that these requirements can be properly solved for all cases only by those who have a thorough knowledge of the fundamental principles that pertain to every industrial activity. This treatment of the subject was so broad as to preclude the opportunity of direct reference to the characteristics of individual plants. Subsequent articles considered the more special necessities of that group of industries in which the working of metal predominates, and in this instance different types of buildings were illustrated, but described only insofar as they were characteristic of types, without reference to their individual peculiarities.

I have not touched upon the innumerable methods, processes, and procedures that are special for given industries, except as covered by the chapters relating to the metal trades and a brief allusion to the hat industry. It is obvious, however, that it is imperative when planning a workshop to have not only a thorough knowledge of the detail processes that will be performed, but also a vast amount of data relating to the proposed business policy of the management. This phase of the entire subject comprises the whole range of industrial handicraft and business policy.

The only way that an adequate idea can be imparted of the inter-relationships and far-reaching influences of all the factors involved, would be to describe in full detail the course of reasoning followed when working up some one complex layout; but space is inadequate to give even a complete exposition of the aims, purposes, and methods of a single business, to say nothing of the uses made of such knowledge as a primary basis for the planning and designing work. However,

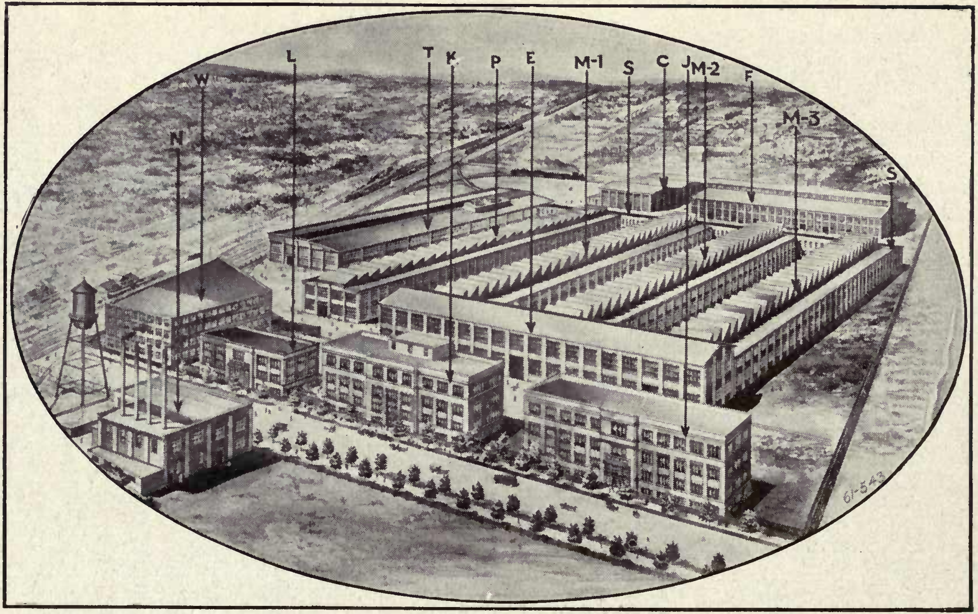


FIG. 26. WAGNER ELECTRIC MANUFACTURING COMPANY.

it would seem fitting, as a separate chapter in this volume, to discuss briefly a number of modern industrial plants which have been laid out substantially in accordance with the methods advocated. Even if the whole story cannot be told, attention can at least be directed to the more interesting features that they possess, and in this way I hope to emphasize the real significance of certain of the matters contained in the earlier publications. With this explanation (which I hope will prepare the reader merely for the presentation of the various points of considerable interest presented by the plants herein illustrated, rather than a logical recital of the manner in which the results were brought about), we will proceed with the first example, which is the large plant of the Wagner Electric Manufacturing Company, St. Louis, Mo., builders and manufacturers of a wide variety of electrical apparatus.

Figure 26 shows in perspective the exterior appearance of the ultimate development of the plant that was finally agreed upon by all parties engaged upon this work. At the time this perspective was made the property was held under option only, there being no structures located upon it. We need not dwell upon the necessity of selecting a new site, as the accommodations occupied previous to the construction of the new plant were wholly inadequate for the volume that the business had already attained, leaving out of consideration a very material increase which trade conditions made immediately imperative. Further, the location in question was only one of a number that were taken under consideration, so that in this particular (and I might say in almost every other respect) there were no limitations imposed that interfered with a correct procedure in connection with the preliminary service. The perspective drawing, Figure 26, is of the ultimate development, and so illustrates a plant considerably larger than the one provided by the company at the time the first construction work was carried out. In this regard "factors" representing the increase in capacity desired immediately, as well as those representing the probable increases that would be required from time to time up to the estimated ultimate development, were carefully figured in advance, and adhered to throughout the work.

The more important divisions of the product made are alternating- and direct-current motors and generators, covering practically the entire range of capacity for which there is demand, transformers of all sizes, auxiliary electrical apparatus such as starting devices and switchboards, and alternating-current electrical measuring instruments. A condition of the work was that the growth of the business would entail merely a greater output in connection with each of the lines just referred to, rather than the probable addition of other lines of manufacture. Therefore, it was necessary to provide for only such departments as already existed, at the same time making provision for the necessary expansion in these departments to meet future requirements. The brief description that follows gives a general idea of the plan of manufacture.

A very considerable amount of cast iron enters into the product, and for this purpose a foundry is provided on the layout that will be adequate for the complete development. The raw material for this foundry is delivered on the siding that passes to the rear of the property as observed from the point of view assumed by the perspective drawing. After the castings are made in foundry "F" they are transported directly across an open way to building "S," which is the raw-material store house, extending across the rear ends and communicating with all the manufacturing and assembling buildings.

All castings used, therefore, must go through the store house before getting into the shops, so they are properly checked up and recorded on the balance of stores record and, if not needed immediately, they remain in this department. All other raw materials are received on the siding that is shown entering the property at the upper left-hand corner of Figure 26, and as it passes directly alongside of the stores building "S," the various incoming materials can be unloaded and carried to their respective bins, racks, or compartments, with the entailment of a minimum expense. This stores building is a two-story structure, the first floor being on the same level as the floors of the main shops, and the second floor on the same level and communicating with the galleries of the main shops, which are shown in the interior view of building "M-1" (Figure 27). In each case the raw product is stored as conveniently as is possible with regard to the building to which it must ultimately be delivered for the performance of the first manufacturing operations.

As the manufacture of sheet-metal laminations is a function that is common to alternating-current motors, generators, and transformers, Building "P," known as the "punch

FIG. 27. INTERIOR VIEW OF ONE OF THE MAIN SHOPS OF THE WAGNER ELECTRIC MANUFACTURING COMPANY.

department," was provided for this purpose. Directly adjoining this department and extending into the area way between Buildings "P" and "M-1" is located the annealing department, the floor level of which is 11 feet 6 inches below the first-floor grade of the main shops. The purpose of this arrangement will be better understood by referring to Figure 28, which is an interior view of a tunnel, extending directly across the plant, perpendicular to buildings "T," "P," "M-1," etc., and located about midway between buildings "S" and "E."

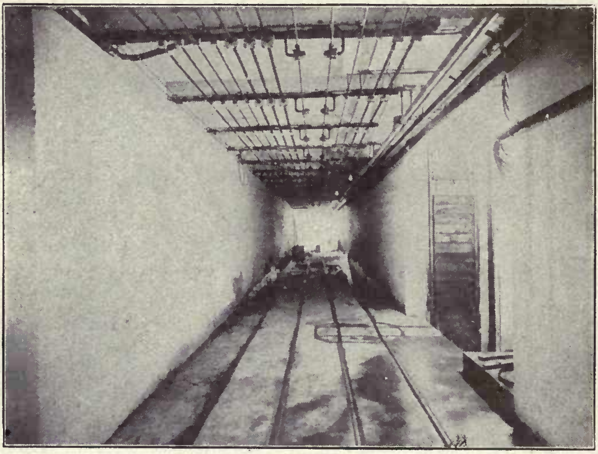


FIG. 28. TUNNEL TRAVERSING PROPERTY OF WAGNER ELECTRIC MANUFACTURING COMPANY.

After the laminations have been pressed out they are lowered on an elevator to the annealing department, which is on the same level as the tunnel floor. If the annealed laminations are intended for the transformer shop, building "T," they are wheeled through the tunnel to the elevator communicating with this building, and in the same manner access is had to buildings "M-1," "M-2" and "M-3" without the necessity of going out of doors or in any way interfering with other work, which would be the case if loaded trucks were being pushed constantly through the various shops.

Motors and generators of various sizes are now made in building "M-1"; the gallery floors and certain sections of the main floor being used for manufacturing work, the machining of large parts, winding, etc., and the balance of the floor space for erection and testing purposes. Building "M-2" will be used for essentially the same class of work, and building "E" for the erection of the largest types of machines that are built. Building "M-3" was provided in the layout to take care of the work on parts and group assembling for the largest product that the company is likely to turn out, and owing to the uncertainty of its character no attempt was made to apportion its space or to determine finally upon the characteristics of the building. Building "J" was provided for the manufacture of electrical instruments; building "K" is the main office; building "L" the service building for employees, and "W" a warehouse for finished product.

The work performed in this plant can be divided roughly between the first two of the three broad classes of metal working discussed in a previous article. The instrument work should be classified under the first division, as it is strictly a manufacturing proposition. The building of large motors and generators comes under the second division, as it comprises a definite line of comparatively heavy machinery. Cross sections of buildings "T" and "M-1" were included in the article in question as illustrating the special character of buildings designed for heavy work. It is only necessary to glance at Figure 27, which is an interior view of building "M-1," to see that the character and dimensions of this shop have been governed in practically every detail by the requirements of the work to be performed in it, and that in many particulars the structure of the building forms the function of equipment. This is true not only in connection with the crane runways, the supports for overhead monorails, and the provisions for elevators, but also in connection with certain features of the equipment proper.

The layout that we are considering is characterized by a series of shops arranged parallel to one another, and connected at one end by a raw-materials storage building, and at the other end by an erection shop, except in the cases of the transformer department, from which finished transformers are shipped direct, and the punch department, which serves the machine shops but not the erection department. Flexibility is secured through the possibility of erecting additional shops paralleling those first erected and at the same time extending the stores and erection departments, so making the additional units an integral part of the plant as a whole until such time as the full development, as illustrated by Figure 26, is attained. This general scheme is by no means new, having been resorted to frequently before the Wagner plant was built, one of the best known illustrations being the plant of the Allis-Chalmers Company at Milwaukee.

Provision was made to segregate all the foundry workers from the employees of the other departments, a condition which is in many cases desirable in order to gain an ade-

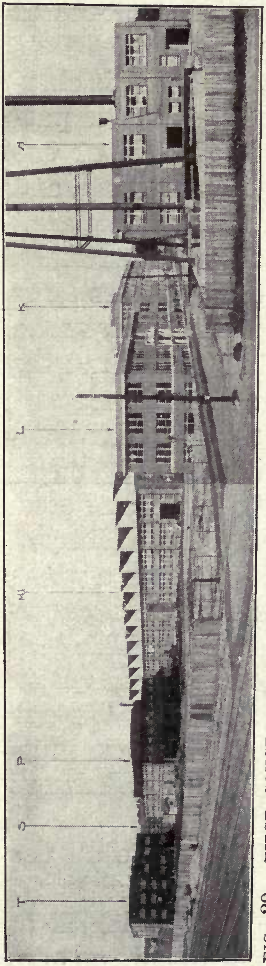


FIG. 29. FIRST CONSTRUCTION WORK IN CONNECTION WITH NEW PLANT OF WAGNER ELECTRIC MANUFACTURING COMPANY.

quate control of the labor situation. The employees of all departments other than the foundry enter the plant through the service building "L," where they dress for their work before going to their respective departments. The time of commencing work, however, is in each case recorded in the departments where they are employed, a condition which is of considerable importance in all large plants. Separate service facilities and entrance and exit to the property are provided for the foundry operatives.

Figure 29, which is a photograph of the

plant immediately after the completion of the first stage of construction, shows clearly the manner in which the necessities of the company as existing at that time were provided for. Buildings "Y," "P," "S," and "N" were erected in part only, but buildings "M-1," "K" and "L" were built as shown on the ultimate development. The temporary ends of buildings "T" and "P" appear in the foreground. Construction of the instrument building "J" was deferred, this work being efficiently provided for upon the second floor of building "P." It was purely special conditions, arising principally through the difficulty of acquiring certain property, which resulted in the location of the power plant, building "N," upon a separate plot, but when the necessity for doing this arose, it was found that no serious objections were presented from the standpoint of power generation and distribution, whereas it appeared that the future would probably develop the need of the property adjoining the power plant for the construction of a multiple-story factory.

A very important consideration that always confronts the industrial engineer is the character of buildings that should be adopted for different businesses. There are usually certain limits of expenditure that are possible, the lowest of which must at least allow of the reasonably efficient performance of the industrial work, whatever it may be, whereas the upper limit represents an expenditure that meets not only the shop requirements proper but those incident to the provision of buildings of a thoroughly permanent character and attractive appearance, incorporating also all the refinements in furnishings and appliances that form a consistent part of such structures. The very nature of some businesses is such that they should not be handicapped by the interest charges that would follow the adoption of recommendations based upon what I have termed the upper limit of expenditures; and in other cases, aside from the utility that the greater disbursement may represent, it is impracticable to secure the necessary funds.

The new plant of the Orenstein-Arthur Koppel Company, built a few years ago at Koppel, Pennsylvania, and recently enlarged in capacity, is a good illustration of an instance where every dollar that was spent went for some positive utility. The plan of ultimate development of their property is illustrated by Figure 30, and Figures 31 and 32 are photographs showing the plan as a whole, prior to its enlargement, and the interior of the erection shop, respectively.

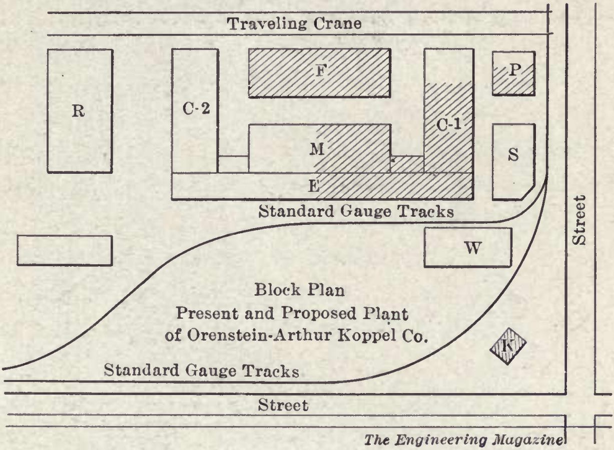


FIG. 30. PLAN OF PROPERTY, ORENSTEIN-ARTHUR KOPPEL COMPANY.

This company manufactures high-grade contractors' equipment, including principally dump cars of all kinds and industrial-track systems. The labor cost per pound upon this product is very low, so it is absolutely imperative that the cost should be burdened with a minimum overhead expense; for in any case it will be a considerable part of the total cost, and unless this condition of min-

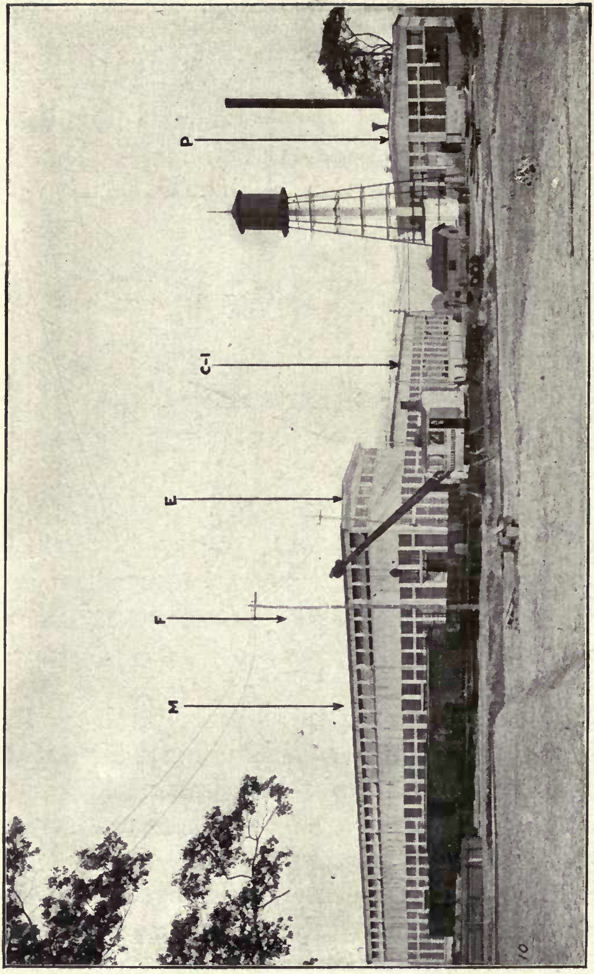


FIG. 31. PLANT OF ORENSTEIN-ARTHUR KOPPEL COMPANY, KOPPEL, PENNSYLVANIA.

imization were complied with the company would occupy a vulnerable position. It was on this account that practically everything was made subservient to utility insofar as this course was reasonable when designing and building the plant of Orenstein-Arthur Koppel Company.

Buildings "C-1," "C-2," "F," "M" and "E" form a complete group for the manufacture of the entire range in capacities of industrial cars of many different types. The raw materials, which comprise principally sheet steel and structural shapes, are received on the siding passing between building "P" and the property line and are unloaded by means of a gantry crane and carried by this crane to the proper section of the storage yard. Building "C-1" is known as the light car shop and building "C-2" as the heavy car shop; the structural and sheet-metal work as well as certain preliminary assembling operations being performed in these departments upon the respective divisions of the product. These shops are served by cranes that operate lengthwise of the buildings and on either side of the central row of columns.

Building "F" is the forge shop, which

serves about equally the light and heavy car work, and building "M" is the machine shop which serves buildings "C-1," "C-2," and "E," the latter being the erection shop, an interior view of which is shown in Figure 32. It will be seen that the arrangement of departments reduces the handling of material to a minimum, a condition which also makes for the most ready supervision of the work. There is no dividing wall between "M" and "E," and by locating the tool room in building "M" directly adjoining the erection department, as shown in Figure 32, it is made most accessible to all the departments it serves. Building "R" was provided for the frog and switch work, building "S" for the storage of miscellaneous raw materials, and an office building, "K," was provided which does not show in the photographs.

The first construction work that was carried out by this company included the erection of the buildings which are cross-hatched on Figure 30. However, the plant has been extended since that time. All the equipment is motor-driven through the medium of either the direct or group method. The power plant, building "P," contains direct-connected generators delivering to the various departments direct current at 220 volts, a three-wire system being used for the lighting. Wherever the requirements made it desirable, adjustable speed motors were installed.

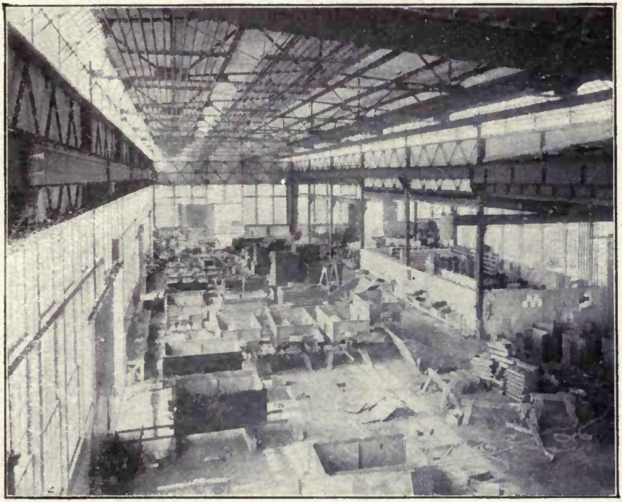


FIG. 32. INTERIOR BUILDING "E," ORENSTEIN-ARTHUR KOPPEL COMPANY.

The interior view of the erection shop, Figure 32, gives a general idea of the type of building construction that was used throughout the plant. The crane runways are supported on a steel frame which carries the roof. The cost of the side walls was minimized and at the same time admirable natural lighting procured through the use of a concrete base course extending from the footing up to a point 6 feet above the floors, and above this base course, extending from column to column, are the window frames, designed for balanced sash in the lower sections. In the case of the erection shop an additional row of tilting sash was installed above the crane runway. This type of construction eliminates entirely the usual pilasters between the window frames. The floors of the various shops are composed of 6 inches of bituminous concrete upon which is laid a 3-inch under floor covered with ⅞-inch factory-grade maple. The roof is composed of heavy plank laid on steel purlins and covered with a form of flexible roofing material.

The greater part of the finished product is stored prior to shipment in the yard directly in front of building "E" and a locomotive crane is used for handling it. A finished-product warehouse building "W" is also shown on the layout. The conclusion that one invariably reaches upon visiting this plant is that money has not been skimped in any particular that makes for economy of operation, whereas not a dollar has been spent for the sake of appearance alone.

While this policy was undoubtedly the correct one to pursue in this case, it would of course be wholly inconsistent with the requirements of many other businesses.

The plants of the Wagner Electric Manufacturing Company and the Orenstein-Arthur Koppel Company are composed of a series of independent shops that adjoin and communicate with an erection shop. As has been previously stated, this type of layout has been adopted quite frequently for certain lines of work. The plant which we are now about to consider is another well defined type, characterized by the condition that all the floor space needed is enclosed under a single room. This procedure is made possible through the adoption of the saw-tooth roof, which eliminates the frequent necessity of providing areaways between separate buildings when roof lighting is not available. Of course the saw tooth type of construction, when it is adopted in the manner that is now under consideration, necessitates the use of a ground floor only.

The plant of the Cincinnati Bickford Tool Company, shown in perspective in Figure 33, has been selected from a number of plants of the type in question as the combination of a number of different kinds of structures makes it a particularly good illustration of the manner in which definite industrial requirements were satisfied and future growth provided for.

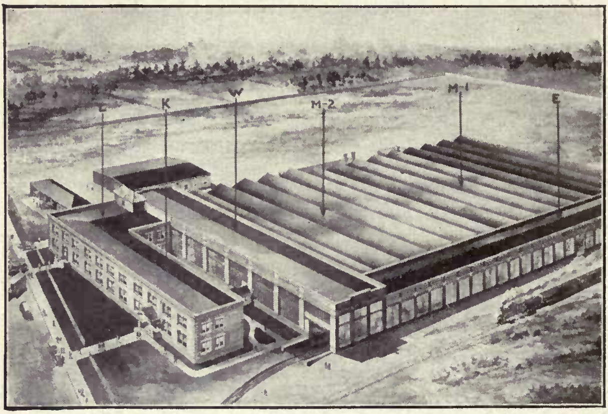


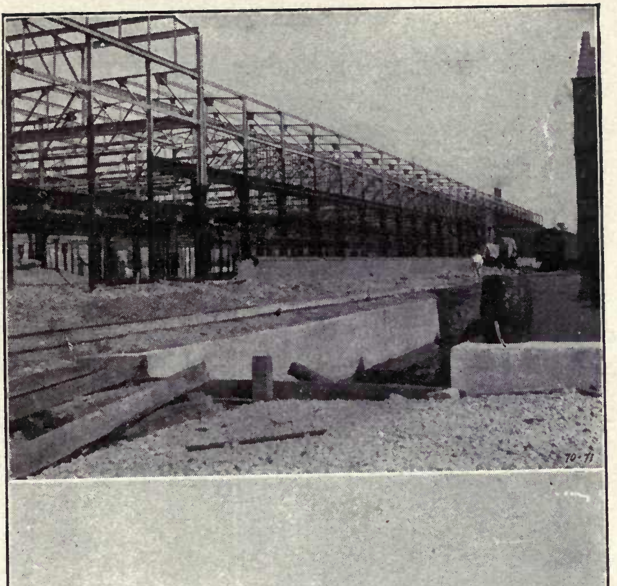
FIG. 33. PLANT OF THE CINCINNATI BICKFORD TOOL COMPANY, OAKLEY, OHIO.

The siding for the receipt and shipment of materials is shown in the foreground. The raw-materials and storage department is at present located in the rear of buildings "E" and "M-1," the front of the property being paralled by the main line of the Baltimore and Ohio Railroad, which does not show in the illustration. Building "E" was designed primarily to accommodate the largest machine-tool equipment operated by this company and the erection of radial drill presses, but a section of it is used for the storage of heavy castings, so allowing for their transportation by means of the overhead traveling cranes installed in this building. The section of the saw-tooth building designated "M-1" is occupied by the machine department except for the space allotted to raw material. The section of this building indicated as "M-2" was designed primarily to accommodate the department for the erection of upright drill presses and the smallest size of radial drill presses, but certain machine tools are also located in this area.

Building "W" is used for the storage of finished product, an overhead traveling crane being provided for the handling of the upright and radial drill presses to the crating department located in this building, and finally for loading them on to the cars that enter the plant on the siding shown clearly in Figure 33. Department "M-2" is equipped with cranes operating in a direction perpendicular to building "W," so that the machines that are assembled in this department can be transferred to the warehouse with a minimum of handling. The construction of that part of the building that accommodates department "M-1"—namely, the machine shop—differs from section "M-2" only in that the headroom is 14 feet under the trusses whereas in the latter case it is 18 feet, the greater dimension being necessary in order to accommodate the erection work that has been referred to previously. Building "K" is a two-story office, and building "L," which adjoins the office and the warehouse, accommodates the pattern shop on the second floor and a service department for the employees on the first floor. The second floor of the office building, which is used by the drafting department, has direct communication with the pattern shop.

Figure 34 is a photograph of the plant during construction, showing the structural steel work of the end of building "W" and the side of building "E." Figure 35 is a photograph taken from the rear of the property looking into the saw-teeth of department "M-1" and showing the end of the erection department to the left. Figure 36 is an interior view of the machine and erecting departments.

The buildings shown to the left of the main plant (Figure 33) were constructed with a



FIGS. 34, 35. NEW PLANT OF THE CINCINNATI BICKFORD TOOL COMPANY DURING CONSTRUCTION.

view to moving or taking them down when the time arrives for extending the plant in a direction perpendicular to the erection shop. The first extension, however, will be made in a direction perpendicular to the warehouse by adding to departments "E" and "M-1."

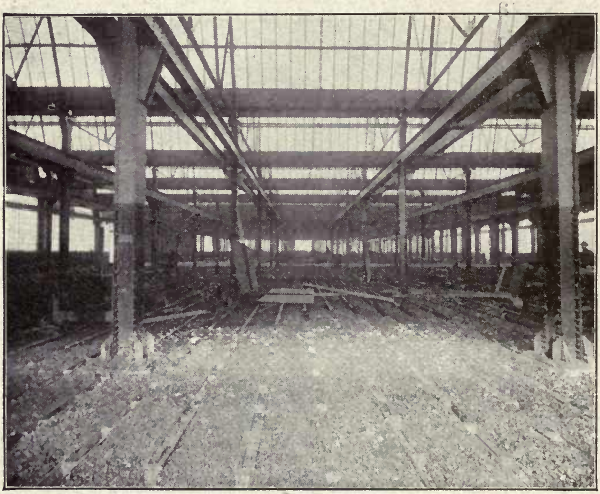


FIG. 36. INTERIOR OF MACHINE AND ERECTING DEPARTMENTS. CINCINNATI BICKFORD TOOL COMPANY.

When the character of the work to be performed in a metal-working plant is such as to make it desirable to use single-story buildings the least amount of real estate is required if the type of layout is adopted that has just been exemplified. It is evident that the Cincinnati Bickford Tool Company will be able to utilize for shop purposes nearly all the property they have acquired if the growth of their business necessitates it.

Metal frames have been used throughout all the manufacturing buildings, both in the side walls and in the saw teeth. The plant is sprinkled throughout and the most approved appliances have been installed in connection with sanitation, etc. A hot-water system of heating has been installed and the entire plant is driven electrically, the steam for the heating and the electric current for light and power being furnished by the central power station which serves the colony of machine-tool builders whose plants have been erected at Oakley, Ohio.

In order to appreciate fully the advantages of the layout that has just been described, it is necessary to have not only a detail knowledge of the business in question but of the series of alternate arrangements or layouts for the new plant which were prepared prior to and resulted in the one herein illustrated. The plant of the Cincinnati Milling Machine Company, adjoining the one just described, differs from it only insofar as the requirements of one business necessitate a somewhat different solution from the other.

A very large percentage of all industrial plants handle a product that is characterized by its small bulk and the light weight of its individual units. It was pointed out in a previous chapter that such requirements are, as a rule, satisfactorily cared for through housing the work in multiple-story buildings, which in one sense may be considered standard in their principal features, as they are suitable for many different businesses coming within the broad class in question. Therefore, insofar as the buildings proper are concerned, the question of layout is not a governing one, it being largely a matter of providing the requisite area. Of course the arrangement of departments and the grouping of equipment is a very vital matter to the business that occupies a building of this character, but for the moment we will not consider this phase of the subject. From this standpoint the principal matters of interest relate to features that make for the desirability of the building in question, irrespective of its occupancy. These are principally the ones of fire-prevention through non-combustible styles of construction, good natural lighting through the provision of a maximum window area, reduction of maintenance charges through the utilization of materials that will undergo the minimum depreciation, the provision of the most approved sanitary arrangements, and means for the prompt exit of all employees in the event of fire, explosion, or other catastrophes. These requirements have been satisfied with varying degrees of thoroughness by those who have recently constructed multiple-story manufacturing buildings, one of the best illustrations being the new plant just completed by the American Optical Company of Southbridge, Massachusetts, for the manufacture of spectacles and eyeglass lenses. This building incorporates all the features which the American Optical Company have found to be desirable from an economic standpoint after having given this subject their closest attention for many years. It represents the most recent attainment resulting from a gradual evolution that had its beginning in a small frame building constructed in 1839. Industrial manufacturing companies rarely consider the subject of their buildings with anything like the thoroughness that has always been the case in this instance, and as

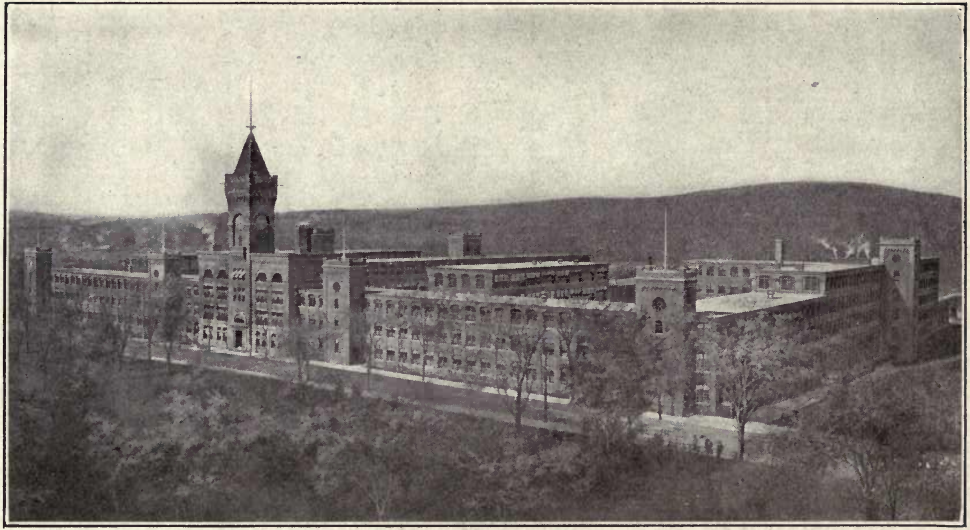


FIG. 38. SHOWING DEVELOPMENT OF MAIN PLANT, AMERICAN OPTICAL COMPANY, SOUTHBRIDGE, MASS, 1910.

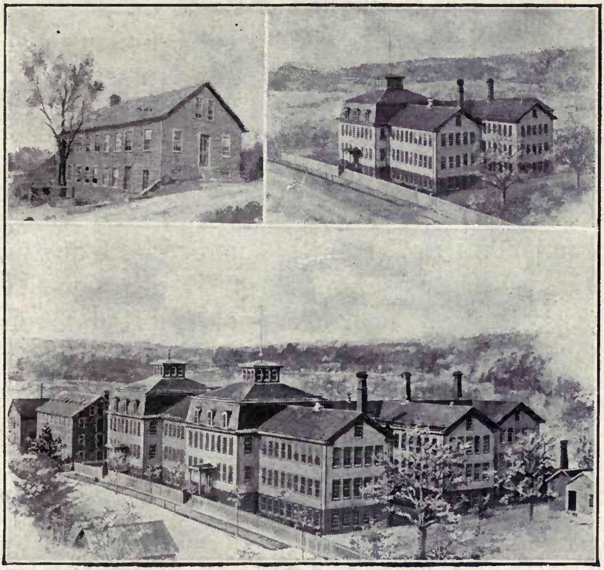


FIG. 37. STAGES IN THE EVOLUTION OF THE MANUFACTURING PLANT OF THE AMERICAN OPTICAL COMPANY, 1839, 1872, 1882.

the procedure adopted at each important stage in the development was thoroughly tried out, the conclusions that have been reached are particularly significant. On this account I will recite briefly the principal considerations that brought about the gradual change in policy, which in the first instance sanctioned frame structures and at the present time dictates the use of wholly fire-proof buildings about to be described. The product of the American Optical Company comprises spectacle and eyeglass frames, lenses and cases of all kinds and types, and in addition certain other allied lines.

The status of the subject of industrial buildings in the year 1839, coupled with the resources of those who commenced at that time the business that has since become the American Optical Company, left but one course of procedure insofar as the plant was concerned; namely, the erection of an inexpensive frame structure. The business grew gradually in the beginning and prior to 1872 extensions were made at the original site. It then became necessary to enlarge the plant still further, and in order to provide for the future a new location was purchased and the buildings constructed that are shown in Figure 37, dated 1872. These buildings were all of frame construction throughout, but superior in many respects to the earlier buildings. Between 1872 and 1882, the plant was extended until it had reached the proportions shown by the third picture in Figure 37.

Throughout the decade immediately prior to 1882 the business grew with very great rapidity, so that the value of the raw materials, finished parts, finished product, special machinery and tools and fixtures housed in the plant, had reached a very considerable figure from the standpoint of invested capital alone; and when appraised as a factor in the perpetuation of the business, its value was, of course, much greater. A realization of this condition emphasized the necessity of making all reasonable provisions for the prevention or isolation of fires, and definite steps were immediately taken toward this end. One of these consisted in the removal in 1897 of all hipped roofs with their slate coverings and their replacement by flat roofs with felt and slag coverings, so eliminating the hazardous attics which formerly existed.

These buildings were also modified in numerous respects in order to render them more adaptable to the requirements of the business which the company was constantly defining with greater accuracy. It was not, however, until 1899 that the first building with brick walls was constructed. The decision to adopt this type, known generally as mill construction, was based upon the resulting reduction in fire risk and maintenance expense and the fact that the problems introduced by greater floor loads than had formerly been imposed could be very satisfactorily solved. After one of the old frame buildings was torn down and was replaced by a larger one of mill construction and brick walls, the advantages of the new structure were so apparent that it was decided to replace all of the frame buildings as rapidly as possible. In this connection it is particularly interesting to note, that it was not possible to keep abreast of the times through modifying from time to time the existing buildings, no matter how radical these modifications might be. The result could be accomplished only through destruction of the old and the building of entirely new structures.

Each building of the mill-construction type that was erected marked an advance in many particulars over those previously erected. For example, in the earlier types the heavy girders were built up by bolting together a number of timbers of the requisite depth but of such a width that in the aggregate they gave the required cross-section. The spaces between these timbers presented a very considerable fire risk, so that solid beams were substituted. The need of providing the best possible natural lighting, owing to the character of work performed, re-

FIG. 39. VIEW BETWEEN THE BUILDINGS, AMERICAN OPTICAL COMPANY.

sulted in the adoption of larger windows in the side walls, accomplished through making the pilasters narrower and carrying the windows as close to the ceiling as was permitted through the use of a brick arch carried over the window head. The single flooring of the earlier types was soon replaced by double flooring, or superseded by it when new buildings were put up. Many of these early features of construction cannot be found in the present plant for reasons that have already been given. As this work proceeded the plant was constantly approaching the appearance illustrated by Figure 38, this entire plant having been constructed in eleven years, as has also a plant, located but a short distance from the main buildings, where all the lens work is done.

Before the plant illustrated by Figure 38 was completed the company adopted brick and steel construction in place of brick and timber. By so doing a greater window area was secured through making the pilasters narrower than before (this being made possible because the brick walls in this case are curtain walls and not bearing walls) and by carrying the windows up to within an inch of the ceilings, accomplished through the very ingenious adaptation of a Z-bar lintel, one leg of which carries the brick wall and the other the flooring, which consists in a 4-inch underplank, 1-inch lining, and maple wearing surface. These buildings incorporate the most approved practice in regard to fire towers and full equipment for the combatting of fires. Figures 40 and 41 illustrate the old and new types of window construction.

During 1900 it became necessary to make separate provision for the lens work, which had outgrown the accommodations available

FIGS. 40, 41. OLD AND NEW TYPE OF WALL AND WINDOW CONSTRUCTION, AMERICAN OPTICAL COMPANY.

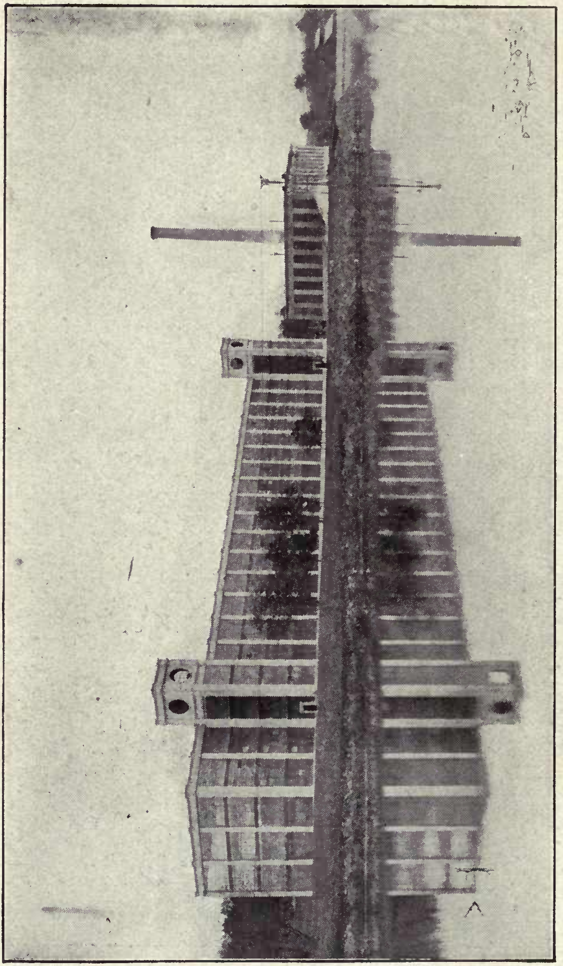


FIG. 42. NEW LENS FACTORY, AMERICAN OPTICAL COMPANY.

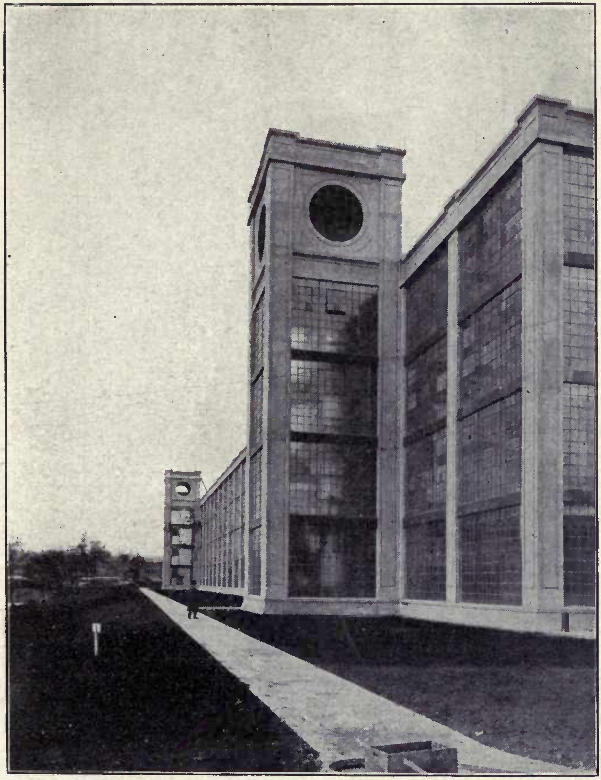
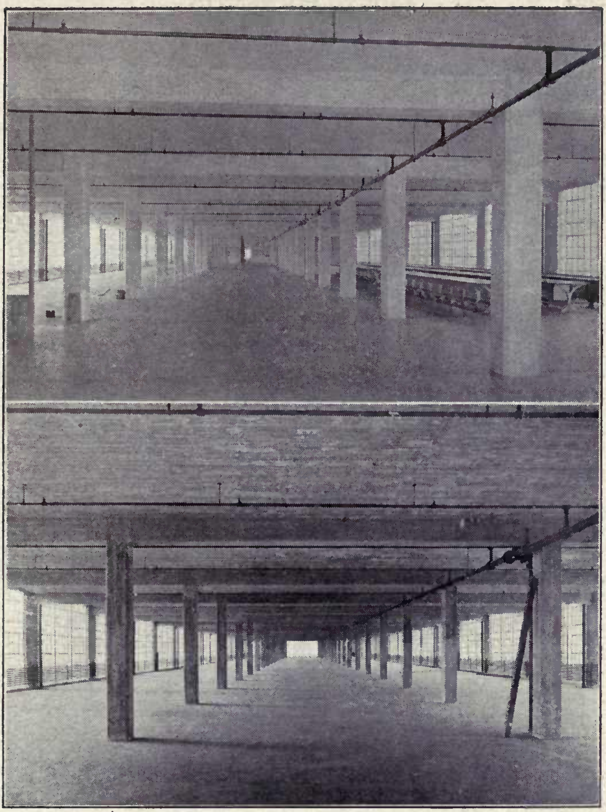


FIG. 43. WINDOW CONSTRUCTION, NEW LENS FACTORY.

at the main plant and further required a special type of building for its efficient performance. The building that was constructed for this purpose is not included among the illustrations but is referred to as it marks a departure from the previous practice to the extent that a concrete floor was used.

The building most recently constructed (1910) is the one illustrated in Figure 42, being the new lens-finishing plant which was referred to previously as being one of the best illustrations of modern multiple-story building construction. Figure 43 is a near view of one of the side walls and shows the stair and elevator towers which also accommodate the toilets. Figure 44 is a photograph of the fourth floor before any painting was done, and shows the floor construction, the extent to which natural lighting has been secured through side windows, and the location of the hot-water pipes for heating. Figure 45 is a photograph of one of the departments that was taken before it was fully equipped and gives a good idea of the appearance of the interior after the painting is completed.

The adoption of reinforced-concrete construction throughout, metal window frames, a sprinkler system, and the absence of any adjoining fire risk, have resulted in the attainment of a minimum fire hazard, and the fact that the windows extend from within a

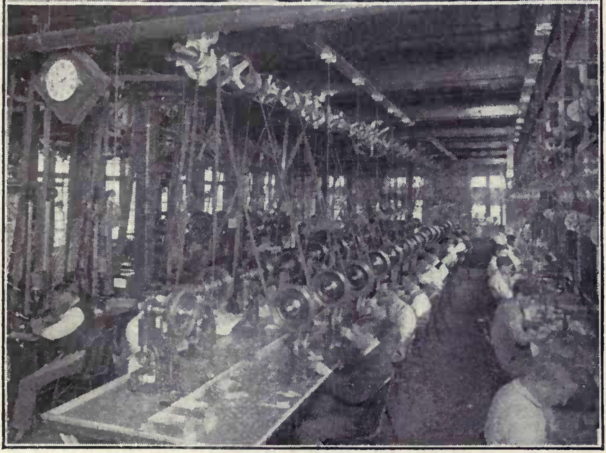


FIGS. 44, 45. NEW LENS FACTORY, AMERICAN OPTICAL COMPANY. INTERIOR VIEW SHOWING APPEARANCE BEFORE AND AFTER PAINTING.

The difference in general illumination of the interior, caused by the painting illustrated in the upper picture, is very marked.

few inches above the floor (a condition consistent with the manufacture of a light product) up to within a few inches of the ceiling, and from pilaster to pilaster, assures the best conditions for natural lighting. The problem of heating has been simplified by double-glazing all the windows. The entire floor areas are available for offices, manufacturing departments, etc., no limitations being imposed through the presence of partitions, stairs, or other enclosures that would interfere with the most efficient disposition of the space. While utility was the motive that governed in the design of this building, yet I think it will be generally conceded that an exceedingly satisfactory and pleasing appearance is presented by the exterior, the simplicity of the treatment being in thorough keeping with the uses for which the building is intended.

A tunnel, 10 feet wide, 8 feet high and about 1,500 feet long, extends from the power plant shown at the right of Figure 38 to the main plant, passing directly under the lens building just described. As the main building is separated from the lens building by a stream, the passageway emerges from the ground and spans the stream, entering



FIGS. 46, 47. NEW AND OLD LAYOUT OF PRESS ROOM, AMERICAN OPTICAL COMPANY.

the main plant above grade. The main object of the tunnel is to carry the water and heating pipes and the light and power wiring.

All the features that have been touched upon so far in connection with the plant of the American Optical Company are governed only along very broad lines, by the special requirements of this particular manufacturing work. If the methods that have been worked out by the American Optical Company for their own buildings are efficient for their purpose, they are equally suitable for many other lines of light manufacturing work. Each manufacturer, however, must make provision which is wholly special in many particulars for the actual work that he intends to do. However, even in this regard there are certaln matters, such as the provision for artificial illumination, method of driving the equipment, the manner of laying out work benches, etc., which present the same essential requirements irrespective of the industry. Figures 46 and 47 show the old and present methods of driving certain equipment in the plant of the American Optical Company, and also exemplify the practices of laying out benches during the respective periods. It is not necessary to dwell upon the desirability of eliminating overhead line and countershafts, for at this time these are generally appreciated. The layout of benches illustrated in Figure 47 is, however, a departure that is comparatively new and possesses many decided economic advantages. Better natural lighting is secured, a greater number of operators can be properly accommodated within a given area, the product can be handed to and from the operators with greater facility, and by having all the operators face in one direction, a more strict attention to their work is automatically secured. Individual lights are provided for each operator. They are mounted upon suitable stands connected by a flexible cord and attachment to the circuit, which is in conduit and made fast to the backs of the benches. There are many other features in regard to the equipment of the plant that I would like to mention, but those just referred to serve as good illustrations as they are thoroughly characteristic. An interior view of one of the main office departments is shown in Figure 48.

While I have described very briefly the evolution that marks the gradual perfection

FIG. 48. INTERIOR VIEW OF ONE OF THE MAIN OFFICE DEPARTMENTS, AMERICAN OPTICAL COMPANY.

of the buildings that from time to time have composed the plant of the American Optical Company, yet it must be apparent to the reader that this development could never have taken place were it not for the unceasing attention to all the problems involved and ability shown in their solution upon the part of the men at the head of this business. I feel especially indebted to them for making available the material that I have used, and wish to take this occasion to thank them for the co-operation that they accorded me.

Chapter XI

VALUE OF AN ENGINEERING ORGANIZATION TO THE PROJECT

ONE of the primary purposes of this book is to emphasize that the efficiency of any industrial establishment, in the final analysis, is governed to no small extent by the effectiveness of the work done prior to the actual commencement of building operations; therefore, neither the need for speedy completion nor any other consideration can be of such importance as to justify superficial attention to this preliminary determination, although frequently progress must be expedited by every known means.

It is evident that, while many of the considerations arising in the construction of industrial plants are wholly special to the business that is to be provided for, there are in addition many factors which do not enter directly into the routine management of the business, but are of the utmost importance when planning the new plant. Most of these are fundamental to the laying out of all kinds of industrial plants, and are, therefore, thoroughly understood by competent industrial engineering organizations. Consequently, if the plant or extension that is to be built is to house other than the simplest kind of work, the best results can be secured only through the joint services of those who will have to do with the management of the business after the plant has been completed, and the members of an engineering organization trained for this particular service.

Further, owing to the nature of the preliminary work, the control and direction of the co-operative service rendered by the owner and the engineers should be vested in one of the members of the latter organization, so centering in one man responsibility for the conduct of the entire operation. The engineering company should assume this responsibility because its management is especially adapted to the proper administration of the work in question, and also because the managers of the prospective plant, in most cases, should be relieved of all detail so that they can properly look after their routine duties, which are usually particularly exacting when a new plant or large extension is being built.

In view of what has been said in the preceding chapters, it will not be necessary to elaborate upon the functions that should be performed by an engineering organization specializing upon the service we are considering. Further, certain other pertinent matters bearing upon this question are dealt with in the next chapter.

The question of financing the construction work usually follows immediately after the completion of the preliminary service, so it will be desirable to give brief consideration to this phase of the subject with a view to determining its bearing upon the work of the engineers.

As a rule, those proposing to build extensions to existing properties or entirely new industrial plants have available in advance (or are, at least, in a position to make arrangements for) certain sums of money which, with the information at hand, they believe to be sufficient for the work. Necessarily, however, final arrangements cannot be made intelligently until the preliminary service has progressed to the point where final estimates are prepared.

It is seldom that the industrial engineer is engaged primarily for the purpose of preparing a report to be used as a means of interesting outside capital, although when it is found that the expenditure that should be made is in excess of the anticipated requirements, a concise report written by impartial experts frequently enables the principals to provide readily for the requisite amount through interests that would not co-operate if the facts were presented in a manner less specific.

It should not be expected, however, that the engineering organization will take a direct part in financing industrial enterprises, although occasionally this is expected owing to the precedent that has been established by engineers who specialize on public-service operations. The two classes of work are in no wise comparable, at least insofar as financing is concerned, and the services of the industrial engineering organization should be confined strictly to matters covered by the preceding chapters. In other words, as engineers are not in a position to guarantee earnings, they should not be expected to assume the responsibility incident to interesting outside capital. The engineers are, of course, responsible for the potential possibilities of the plant provided under their direct supervision, but their engagement is invariably terminated upon the completion of the plant, so they can in no wise control the results of operation. In contrast to this condition, there are engineering organizations who perform all preliminary and detail work required in connection with public-service plants, and in addition operate the properties they have built. When they accept responsibility for all these functions their interest becomes, in a certain sense, that of engineer and owner jointly, and the opportunity is afforded to substantiate their own predictions as to gross income, operating expenses, etc. Under these circumstances, if it is desirable, the engineer can rightly take a hand in the financing of new work.

I have dwelt upon the above only for the purpose of emphasizing an understanding that should be primarily established as a basis for any arrangement covering the employment of professional men: namely, that the limits of responsibility for the securing of results by a certain procedure should be clearly defined, the responsibility ceasing with the surrender of the control of matters upon which the predicted results depend. The confidence that must necessarily be placed in engineering organizations by those employing them for preliminary industrial work is evidenced by the fact that their recommendations are accepted with the knowledge that it will be the owner's responsibility to prove during subsequent operations the correctness of the plant in all its details.

The brief manner in which it has been necessary to touch upon the method of preparing detail plans and specifications required in connection with the building of industrial plants is likely to give a quite inadequate understanding as to the character of the service in question, except to those who are to some extent familiar with the work. It is not necessary, however, for those who intend to build an industrial plant or to extend an existing property to be familiar with the manner in which each of the engineering details should be cared for, but it is of the utmost importance that they should be properly advised as to the general procedure that will bring about an efficient result; that is, to whom the work of preparing detail plans and specifications should be entrusted.

While the value of the services of engineers in connection with the preliminary work has not received pronounced recognition until within the past few years, it has for a long time been customary to engage architects for the purpose of having prepared building plans and specifications, and engineers have been employed almost as generally in connection with the purchase and installation of equipment for lighting, heating, and power purposes. As a matter of fact, architecture, in the strict sense of the term, usually plays a minor part in connection with the building of an industrial plant, as all matters having to do with the integrity of the structures are purely engineering considerations. If an architect is competent to handle the work that we have under consideration, it is because his organization comprises engineers possessing the training and experience which the operation necessitates, or that he associates with engineers for the purpose of securing this end. On the other hand, an engineering organization fitted for the proper performance of this work must either include among its members one or more competent architects, or depend upon their ability to secure the co-operation of architects practicing independently. However, engineering companies, as they attain reasonable proportions, invariably find that their work can be efficiently handled only through the inclusion in their own ranks of all the various kinds of ability demanded for the complete performance of the majority of commissions secured, so that it should be assumed that the term "Engineering Organization" includes, as one of the contemplated functions, the performance of such architectural service as enters into industrial operations.

Occasionally an industrial company that maintains a designing department, as a regular part of its organization, decides to prepare through its own force the plans and specifications required for an addition to its plant, believing that its needs can be efficiently cared for by merely augmenting its staff. As this view is now but rarely evidenced, time would not be taken to point out wherein it is fundamentally in error were it not that by so doing it is possible to make more clear the administrative conditions necessary for the efficient handling of the work.

In the first place, the designing department or drafting room required by a manufacturing company operates under conditions that are radically different from those governing the administration of the same department of a company organized especially for the purpose of handling miscellaneous engineering operations, so that while the employment of engineers or draftsmen familiar with building work may provide a part at least of the technical and possibly practical knowledge that is required, it does not provide that much more essential element which can be described as an efficient organization for control. Of course, the owners may to some extent appreciate this fact and so start out with the intention of employing a first-class man to take charge of the work in its entirety. If by chance they are successful in this, the man so engaged will insist upon entire control in accordance with his own views, so that the owners, to all intents and purposes, will have engaged an engineering organization, but one which cannot bring to bear upon the solution of their problems the advantages of the data and systematic co-operation that would be available if they engaged an established engineering firm.

It may be asked why the industrial company should be considered incapable of economically preparing its own detail plans and specifications, and my answer would be briefly as follows: the entire scope of experience which the management of the industrial company can bring to bear upon the problem is incorporated in the conclusions resulting from the preliminary work. The preparation of detail plans and specifications is a matter wholly outside of the specialty in which they are engaged, so they are handicapped at the very beginning through their inability to judge as to the competency of the men they employ, and they are equally unable to check properly the value of the work that is done. If, on the other hand, the industrial company decides to engage an engineering organization, no attempt need be made to determine the ability of the individuals composing the various organizations under consideration, but decision must necessarily be based upon an investigation of their work for others.

Assuming, however, that engineers and draftsmen are engaged first hand by the industrial company, let us consider their probable environment. They will find that the existing designing force, if there is one, is performing work which is in a certain sense quite independent of the routine manufacture performed in the plant, this being more true as the manufacturing work is more nearly repetitive in character. The designers are usually working upon modifications of the output which the company expects to place on the market at some future date with a view to improving its character, reducing its cost, or both, and the drawings are necessarily made the subject of minute discussion upon the part of all the principals and department heads. Drafting-room expense which at first sight might appear to be exorbitant may in reality be more than justified through the enormous repetition of an increment in saving. The conditions in regard to the work for which the new men are employed are, in many respects, diametrically opposed to those just defined. Insofar as the buildings proper are concerned, it is only the big things (which are readily evident, and all defined by the preliminary work), that bear upon economy of future operation, and such minute attention to details as is usual with the designer employed by an industrial company is wholly unwarranted. By this I do not mean that the work can in any way be slighted, but rather that the members of an engineering company organized for the designing of new plants are trained to understand that designs which are for something that has never been built before, and will probably never be used again, must be made right the first time, and it is the province of the engineers to define the limits of accuracy that are appropriate for each case. Now, it is just at this point that the industrial organization attempting to do its own work becomes involved in needless confusion and expense. Irrespective of the training that the draftsman engaged for the purpose may have had, the chief engineer or chief draftsman will unconsciously endeavor to apply his customary methods; and in this he is at a further disadvantage through his lack of familiarity with the methods and practices of the shops that will be called upon to build the parts that are being designed. It is especially hard for him to acquire the mental attitude that permeates the successful engineering organization, and springs from the knowledge that as long as the work is in the drawing room, the field work is wholly or partially delayed. In fact, the habit of discussion and revision is so much a part of industrial management that it is frequently responsible for the expenditure of weeks where as many days should be sufficient.

We need not at this time discuss further the advisability of engaging engineering specialists for the purpose of preparing detail plans and specifications for industrial plants. If any of my readers are particularly interested in this matter, they should read the admirable article published in the May, 1908, issue of THE ENGINEERING MAGAZINE, written by Mr. Frederick W. Bailey. In criticism of the practice of industrials who design and build their own plants, Mr. Bailey concludes:

> Such a system, of course, will eventually hang itself. Plants will finally cost so much to build that they cannot be operated at the profit which competitors make. Finally, perhaps upon the consolidation of several plants, a broader view of specialization will come to those in control, and it will be seen that true economy lies in letting engineers build the plants, while operators confine themselves to operating them.

Chapter XII

COMPENSATION FOR ENGINEERING AND CONSTRUCTION SERVICE

REASONS have been given in the preceding chapters why industrial managers who propose to build new plants or extend existing properties should secure the co-operation of an engineering organization proficient in this respect.

There is no way of accurately estimating the amount of time that will be required for the *preliminary work* on the part of experts, as every commission presents different conditions as to the basic data that have been compiled and the thought that has been devoted to the questions at issue prior to the engagement of such specialists. The investigations made at this time may lead to a prompt solution, or they may develop a complex situation necessitating much research and the consideration of a number of alternate plans. Therefore, the charge for preliminary industrial work performed by engineering organizations can be made equitably only upon a basis of the actual time required for its performance, daily rates being agreed upon in advance covering the services of the engineers who are needed. Industrial managers at times take exception to the rates which an engineering organization must charge for this work in order to make it yield a profit. They are primarily familiar with the sale of a product that can be weighed on a balance or measured with a rule, and on account of the manufacture in large lots, the labor charge per unit for the initial creative work that made the article possible is either practically negligible or is not taken into account. As the engineers' conclusions are made clear through the medium of reports and blue prints, which in themselves cost but a trifling sum, those who contemplate the employment of engineering experts are apt to jump to the conclusion that the daily rates represent clear profit. While they are familiar with the overhead expenses that occur through the conduct of their own business, they cannot see any reason why expenses of this character, comparable with their own, should be incurred by an engineering organization. This view comes about through their failure to comprehend the gap that exists between the consulting engineer of the old school and the highly perfected engineering organization of today, employing possibly from fifty to several hundred men in office departments alone. The actual facts are that the overhead expenses of such an engineering organization as we have under consideration will amount to about 100 per cent on productive wages when extremely favorable conditions hold. This figure is given authoritatively as a result of inquiry among leading firms. Insofar as the owner or client is concerned, however, this expense should be considered to be almost as productive as the direct wages paid to men engaged on his work, as it goes to provide all the facilities and means that enhance many fold the knowledge and experience of the very men who are working in his interests. It maintains a statistical department that assures to each client not only the benefit arising through all other work done within the organization, but advantages that follow ready reference to the work of others. The average owner does not realize that if it were not for the enormous fund of data that engineering organizations have compiled at the expense of much time, they could not begin to complete their respective commissions anything like as promptly or effectively as they do. The housing of a large staff of men for this work involves heavy expenses, but it is through the fact that all kinds of ability and experience are available within the same office, that the organization possesses a value to its clients that could not be secured by independent workers. Those who have endeavored to carry out large undertakings through engaging a number of independent specialists are usually willing to testify to the difficulties and delays that arise. Consequently, we see that while the owner might by chance be successful in employing directly one or more engineers of unquestioned competency, he can never hope to secure those necessary adjuncts which form the backbone and fiber of the engineering organization, the maintenance of which creates the overhead charge.

Now to put it squarely, I ask those who are responsible for the planning and building of a large industrial plant: "Are you willing to entrust the preliminary service, upon which the ultimate success of your entire enterprise is to no small extent dependent, to men whose training, experience, ability, and initiative have not brought them to a point where they command salaries of at least $5,000, or at the rate of about $17 per working day?" If you are not, then you must add to this an additional $17 for overhead expenses, making the total cost $34 per day, so that if the owner pays $50 a day for the services of such a man, the profit to the engineering organization cannot possibly exceed $16. As a matter of fact, it is hardly necessary to point out that in even busy periods such a man's work cannot be arranged so that he is engaged at this rate for 300 days in a year, and further fluctuations in business result in an average overhead expense, taking good years with bad, more nearly approaching 125 per cent, so that the rate of $50 assures in reality but a very small margin in proportion to the value of the service rendered, which value, I wish to repeat, springs principally from the resources of the organization, and not the experience of its individual members.

The recital of facts just presented will make it clear, it is hoped, that expert fees ranging from $50 to $150 per day may represent only a very modest profit, whereas the far-reaching effect of the services secured through incurring such expense may be such that the amount is wholly nominal in view of resulting economies of operation. Engineers expert in public-service work have for years been receiving these rates, the actual amount, of course, depending upon their experience and standing; and certainly the preliminary work performed by the industrial engineer is quite as far-reaching and, in the majority of cases, much more involved than the initial investigations pertaining to public service properties.

The practice of making the charge for the preparation of detail plans and specifications a percentage of the cost of the operation has long been established, and insofar as building work is concerned, this method is practically universal. The rulings established some years ago by the American Institute of Architects have been adhered to generally by competent architects and engineers who prepare such plans and specifications, and until very recently this schedule of charges was briefly as follows: for entirely new work a minimum commission of 5 per cent of the final cost of the operation, which in special cases has been lowered upon the authority of the Institute, plus the wages and expenses of one or more superintendents of construction located permanently on the work, and also traveling expenses. This fee provides for the making of preliminary sketches, preparing detail plans and specifications, securing bids, letting contracts, and superintending construction. Three-fifths of the total fee, (amounting, in the case of the minimum, to 3 per cent) is for the completion of the work up to the letting of contracts, and the remaining 2 per cent is for the latter service and supervision. As the schedule was drawn specifically as a basis for architect's fees, special rulings were included providing that the owner should reimburse the architect for any expenses legitimately incurred through engaging specialists in connection with equipment details such as heating, ventilating, and mechanical, electrical, and sanitary problems. Unfortunately, the intent of those who prepared this schedule has been widely departed from through the minimum fee being applied to many cases in connection with which a larger fee would be proper and should have been arranged for.

The strictly architectural work incident to the building of industrial plants is usually subordinate to the engineering service, and as engineers have never formulated a standard schedule of charges for their work, but have been guided largely by the rulings of the American Institute of Architects, the matter of their compensation has never been authoritatively established, and is at present in a very unsatisfactory state.

I feel that this book regarding the planning and building of industrial plants would not be complete unless I take up in some detail the conditions which on the one hand have resulted very recently in the establishment, by the American Institute of Architects, of a minimum fee of 6 per cent, and which, further, are likely before long to bring about the formulation by engineers of a definite basis of charges for the preparation of plans and specifications covering engineering features.

While the percentage plan has certain advantages through its simplicity, and the fact that in general it provides for a sliding scale whereby the compensation increases with the magnitude of the operation, yet as previously mentioned, through the too general acceptance of the minimum fee as a basis of compensation for work of widely different character, its application has proved to be very crude and inadequate as a proper measure of the actual expense incurred.

The inconsistency of a charge based upon a fixed percentage, irrespective of the character of the operation (which was never intended) can be made more clear by citing a few typical illustrations. The plans and specifications needed in building plants for industries which have been largely standardized and require very simple structures, can be readily and economically prepared by those specializing on such operations; whereas many less specialized industries impose unusual conditions that prevent strict adherence to any established precedent. The engineering organization which devotes particular attention to the building of cement plants or cotton mills arrives at certain clearly defined views as to layout and design, and in many instances the only conditions presented by a new commission requiring special study are those relating to output, probable growth, and the specific property. As a rule it is the number of building units and amount of equipment that are chiefly affected by these matters, so that construction details which have become a matter of record can be directly adopted, and in many cases the desired result is promptly and efficiently obtained through the modification of existing drawings and specifications.

In comparison with this illustration let us consider the work that must be performed by the engineering organization engaged to prepare plans and specifications required in connection with buildings and equipment suitable for the manufacture of storage batteries. At the present time there are not more than four or five concerns manufacturing storage batteries upon a large scale, and it is only at wide intervals that the need of building a new plant or large extension for the accommodation of this work arises. Therefore the amount of business in this particular field available to the architect or engineer is not sufficient to permit of specialization; and even if an organization engaged for the purpose of designing such a plant had formerly been employed by another client in the same line of business, a knowledge of the designs made in the former case would probably be of little avail. Radically different views exist as to many of the primary features involved, partly because different processes are used by the various concerns in this business, and partly because the number of plants that have been built is too small to emphasize the marked advantage of any one type of structure. Of course, many of the special features involved in such a plant are thoroughly considered during the course of the preliminary work, which service, for our present purpose, must be considered as quite distinct from that of preparing the details, plans and specifications. However, this industry presents numerous problems (one of which is that of providing against the destructive action of the sulphuric-acid fumes) which must be kept in mind when working up the details. When these matters have not been previously investigated, a large amount of research may be necessary, the results of which may have a very important bearing upon matters of design and construction. Then again, frequently many of the smaller industries can be most advantageously housed by accommodating different departments in distinct structures, each comparatively small in extent, and either independently located or merged together, but in any case necessitating an amount of engineering consideration greatly in excess of that required to design a standard building composed of uniform bays, but requiring the same outlay.

The inequality of conditions presented by the two broad classes to which I have called attention, is, however, wider than would appear from the above, for it is customary, and often necessary, to invest in cement plants and cotton mills much more money for buildings and equipment than is provided for many of the more miscellaneous industries. Therefore, there are plants that to a certain extent at least have been standardized in layout and building and equipment details, and at the same time trade conditions are such that the provision of the required facilities necessitates large expenditures. A fee that would yield a proper profit for the preparation of the plans and specifications under such conditions would represent a percentage of the total cost that certainly would not be an equitable basis for the performance of a similar kind of work in connection with the provision of buildings for the majority of industries, in which the outlay necessary to provide for customary output is much less, but the actual expense of making detail plans and specifications considerably more.

While for the present purpose it may not be necessary to analyze the situation further, yet it should be pointed out that even for a given industry the expense involved in connection with the preparation of plans and specifications for new buildings and equipment does not increase directly with the size of the operation—that is, its total cost—but at a somewhat lower rate. Designing a cement plant for 5,000 barrels per day does not necessitate a great deal more study and drafting work than designing a plant for 2,000 barrels per day, nor does a storage battery plant for an output of 200 cells per day require a great deal more designing work than one for 25 cells.

No differentiation has been made between the preparation of plans and specifications for buildings proper and those needed in connection with the manufacture and installation of equipment, for in general the same line of reasoning applies in both cases. A considerable part of the equipment used in industrial plants is built upon a manufacturing basis, and the engineer's function is merely that of selecting the type and make that best suit the requirements. On the other hand, there are cases where special processes necessitate the use of apparatus which is not available and therefore must be designed and built for the purpose. And then, again, there are requirements which can be satisfied in part through the use of standard apparatus, but need also certain special auxiliary appliances to make the equipment complete. Consequently the actual engineering expense varies greatly when providing equipment which necessitates the preparation of specifications and suitable information to accompany them, together with a proper consideration of the data received with the bids. The records of an engineering organization handling a wide range of work show that while this expense may not exceed 3 per cent when purchasing standard industrial apparatus and power-plant equipment, it frequently runs up to 15 or 20 per cent, and occasionally much higher, when detail designs must be made for apparatus that is wholly or in part original in its conception.

A proper recognition of the conditions to which reference has been made must convince the owner, architect, and engineer that a given percentage, irrespective of its amount, cannot be expected to provide equitable compensation for all classes of work. The majority of owners, of course, are quite unfamiliar with the character of work required on the part of the architect or engineer in order to render efficient service, and they have even less knowledge of the cost incurred through its performance, nor can it be expected that conditions should be otherwise. They should realize, however, that the very nature of the service is such that any conditions that tend to establish an incentive for superficial work may prove most damaging in the ultimate result.

Competitive conditions among architects and engineers, together with this lack of knowledge upon the part of owners, have resulted in the establishment of a fixed percentage fee, which, in the majority of cases, will assure a profit only when expenses are minimized through the adoption of a procedure that is detrimental to the owner's best interest. Evidences of this are numerous, the most prominent illustrations being the transfer of the preparation of plans and specifications from the office of the architect or the engineer to the office of the contractor or manufacturer. The contractor, of course, urges the adoption of this method as it places him in a somewhat more advantageous position when bids are solicited, and in some cases by this means he is able to eliminate competition entirely. This refers, of course, to such features of the work as should be cared for, without doubt, in the office of the architect or engineer. The primary object in preparing detail plans and specifications, in the manner outlined in a previous chapter, is to define clearly the character of the structure or apparatus desired, and to establish an impartial basis for competition. When the contractors or bidders make their own plans and specifications for such matters as structural steel work, piping systems, etc., comparison of performance, and therefore of prices, is frequently very difficult. Further, the contractor includes in his bid an amount for the preparation of such plans and specifications so that ostensibly the owner is paying for the work twice. On the other hand, architects and engineers as a class have been forced into this position through their lack of aggressive and united action. Analysis of the records of such firms as have been able to create profitable businesses without sacrificing thoroughness invariably shows that, upon a 5 per cent basis, the cost of much of their work amounts to, or even exceeds, the figure that this commission will realize. It is only the large and comparatively simple operations that can be made to yield a reasonable profit on a 5 per cent basis.

Fortunately this condition has been partially corrected through the action of the American Institute of Architects establishing a minimum fee of 6 per cent above referred to; but a relationship between owner and architect or engineer tending to promote efficient service will not be attained until the conditions that have been outlined are properly appreciated, and until owners recognize that when arranging for such service as we have had under consideration, their interest will be best served through carefully considering all reasons that may be advanced in justification of a given commission. This is especially true if the amount of the commission happens to be in excess of the minimum, owing to the belief on the part of the architect or engineer that the conditions are such as to necessitate a special charge.